EXHIBIT A

Expert Report of Daniel Schlenk, Ph.D.

City of Spokane v.
Monsanto Company, et al.

Submitted by Daniel Schlenk, Ph.D.
October 11, 2019

Ecological Risk Assessment for PCBs in the Spokane River

Daniel Schlenk, PhD
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I. Qualifications:

Daniel Schlenk, Ph.D. is Professor of Aquatic Ecotoxicology and Environmental Toxicology at the University of California Riverside. Dr. Schlenk received his PhD in Toxicology from Oregon State University in 1989. He was supported by a National Institute of Environmental Health Science postdoctoral fellowship at Duke University from 1989-1991. A Fellow of AAAS the Society of Environmental Toxicology and Chemistry, he has served on three Scientific Advisory Panels supported by the California State Water Board in the USA focused on the monitoring of recycled and surface waters for Emerging Contaminants. Since 2016, he has been a permanent member of the USEPA Chemical Safety Advisory Committee, and from 2007-2014, he was a permanent member of the USEPA FIFRA Science Advisory Panel, which he Chaired from 2012-2014. He is currently an Associate Editor for *Environmental Science and Technology*, and *ES&T Letters*. He currently serves on the editorial boards of *Toxicological Sciences*, *Aquatic Toxicology* and *Marine Environmental Research*. He has published more than 285 peer reviewed journal articles and book chapters on the identification of Molecular Initiating and Key Events within Adverse Outcome Pathways for emerging and legacy contaminants in wildlife and humans. He has particular expertise in the linkage of molecular and bioanalytical responses associated with neuroendocrine development and whole animal effects on reproduction, growth and survival. He has been a recipient of the Ray Lankester Investigatorship of the Marine Biological Association of the United Kingdom; a visiting Scholar of the Instituto Del Mare, Venice Italy; a visiting Scholar in the Department of Biochemistry, Chinese University of Hong Kong; a Visiting Scientist at the CSIRO Lucas Heights Laboratory, in Sydney Australia, a Distinguished Fellow of the State Key Laboratory for Marine Environmental Science of Xiamen University, China, and Outstanding Foreign Scientist at Sungkyunkwan University in Korea. His research is supported by funding from the USGS, NIEHS (Superfund Research Program), and USDA.

I have given no expert testimony in the previous 4 years. My rate for testimony is $600 per hour.

II. Summary of Opinion:

- PCBs pose a hazard to benthic invertebrates based on PCB residues in sediments collected in the Lower Lake Spokane.
- PCBs pose a hazard to at least one species of fish at Upper Lake Spokane and Above Monroe.
- PCBs pose a hazard to fish consuming biota (bird and mammals) throughout the Spokane River. Examples of mammals affected by dietary exposure to PCBs due to fish consumption include black bears, raccoons, mink, and river otter. Examples of birds, include herrons, osprey, white pelican and bald eagles.
- Following the City of Spokane's proposed remediation measures, sediment concentrations of tPCBs in Lake Spokane were lowered below hazard thresholds.
- Although fish tissue concentrations remain above PCB threshold levels following the City's proposed remediation, the City of Spokane would reduce the ecological risk posed by PCBs by reducing the amount of PCBs entering the River.

III. PCB Overview

Polychlorinated biphenyls (PCBs) are chemicals found throughout the environment derived from human synthesis. Used in various industrial and consumer product applications, PCBs are extremely stable. Due to their recalcitrance to degradation, PCBs can be significantly persistent in the environment.

With chlorine atoms occupying, in some cases, all carbons within the molecule, some PCBs are also recalcitrant to biodegradation, which normally occurs via oxidation or reduction reactions on carbon atoms that do not have chlorine bonds. In general, the higher the chlorine number per molecule the more recalcitrant to degradation. Because there are multiple carbons available on any given molecule (e.g. 10), PCBs exist as multiple forms known as congeners, which are numbered from 1-209. PCBs have also been described as mixtures based on total chlorine content of the fluid. For example, Aroclor 1254 had 54% of the fluid as chlorine. Examples of other Aroclors include 1260 and 1248.

Each congener has a unique chemical structure that can have congener-specific biological activity in organisms exposed to them in the environment. For example, PCBs that have a co-planar structure have a biological activity different from those are not co-planar. The co-planar congeners bind and activate a receptor known as the aryl hydrocarbon receptor (AhR), which is how some of the biological effects occur in primarily vertebrate animals. The co-planar congeners (e.g. 126 and 77) have the highest binding affinities for the AhR, and the AhR-mediated biological activity of mixtures of PCBs can be

calculated based upon their individual binding affinities for the AhR. These calculations are called Toxicity Equivalent values or TEQs.

Ecotoxicological Impacts

Due to their persistence and relatively potent biological activity, PCBs were banned for industrial use in 1979. Biological activities of PCBs range from cancer, to immune suppression, to developmental impacts to endocrine disruption (thyroid hormone and estrogen hormone levels), to reproduction impairment, and nervous system damage (ATSDR 2000). Many of the effects depend upon the specific structure of the congeners (co-planar or non-co-planar) to which the organisms are exposed.

Due to the trophic transfer of persistent PCB congeners, apex predators such as fish-consuming mammals and birds are quite susceptible to the toxicity of PCBs. Enhanced mortality, decreased reproductive success, and several outbreaks of disease in colonial fish-eating birds was observed in the Great Lakes basin and shown to be causally linked to PCBs (Giesy et al. 1994). The malformations (cardiac edema, and skeletal effects) were identified as GLEMEDS (Great Lakes embryo mortality,edema,and deformity syndrome); and the syndrome correlated with bioaccumulation of coplanar PCB congeners (i.e. PCB 126,169,and 77) (Fry 1995). When fish-consuming mammalian species (i.e. mink) were fed fish from a PCB contaminated location in the Great Lake system, reproductive and developmental dysfunction was observed that mimicked the observations in the environment (Heaton et al. 1995). In the Hudson River, as recently as 2012, when mink were fed a daily diet composed of less than 10% Hudson River fish, a dietary concentration of ∑PCBs was present that resulted in 20% kit mortality as well as other developmental abnormalities (Bursian et al. 2013). Similarly, in fish, blue-sac disease which was a developmental cardiotoxic effect noted in fish embryos and larvae was directly linked to AhR activation by co-planar PCBs and other chemicals that bind AhR such as dioxins (Hornung et al. 1999). Impairment of cardiovascular function in early life stages of fish by coplanar PCBs has been linked to early life stage mortality (TAMS 2000). Salmonid fry mortality has also been observed following PCB exposures (Mac&Seelye, 1981; Berlin et al., 1981).

Sublethal toxicity has also been noted in salmonids and included immune suppression, thyroid hormone disruption, and changes in female egg yolk proteins that can impair reproduction (Meador et al. 2002).

Effects on benthic (bottom dwelling) organisms are less clear. Generally effects on survival are used to set toxicological thresholds, but sublethal impacts on reproduction and growth may also occur. Effects of PCBs on periphytic algae are also less studied, but the periphytic biolayer was shown to be a significant sink for PCB concentration. The accumulation capacity of periphytic biolayer to PCBs was one order of magnitude greater than that of sediments on a TOC basis (Wang et al. 1999). Thus in areas with limited sedimentation such as the Spokane River, periphyton can serve as a trophic vector in food webs that allow transfer from water to higher trophic organisms such epibenthic invertebrates that feed on the algae and fish that feed on the invertebrates or algae.

IV. Spokane River Assessment

Problem Formulation

In 2001, the Washington State Department of Ecology conducted an Ecological Risk Assessment on the Spokane River. The primary contaminants of concern were PCBs. Concentrations of PCBs were measured in fish, sediment and water of the Spokane River and a Hazard Assessment was conducted evaluating risks to aquatic life and fish-eating wildlife. Based on the available data and toxicological benchmarks used in the assessment, the primary ecological hazards identified were:

1) possible adverse effects on the sustainability of fish populations and fish-eating mammals, primarily in the reach between Trentwood and Nine-Mile Dam; and
2) possible adverse effects on benthic invertebrates in the Trentwood to Monroe Street Dam reach in areas where PCBs have been concentrated in fine-grained sediments, such as behind Upriver Dam.

The ecological hazard due to the PCB levels in Long Lake and in the Spokane Arm was considered low. The Assessment concluded that at the time fish-eating birds did not appear to be at risk in any part of the river.

To determine whether risks are still present in the river and to incorporate more recent effects thresholds, I've conducted an updated assessment. Consistent with the 2001 assessment, PCBs are the chemicals of concern for this assessment. The general fate of PCBs in aquatic ecosystems is based primarily on their binding to dissolved organic carbon, or carbon within suspended sediments, and subsequent movement into bed sediments. Due to uptake by benthic invertebrate prey from sediments or carbon, fish and fish-consuming organisms undergo exposure through trophic transfer. Aqueous exposure to fish may also occur.

To evaluate the risk of PCBs to biota in the Spokane River, measured concentrations in tissues or sediments will be compared to literature-derived threshold for adverse effects.

For sediments, benthic invertebrates will be targeted for risk assessments.

To assess risk to fish, tissue based exposures of total PCBs will be compared to thresholds for fish toxicity. PCBs will be listed as total congeners by wet weight in both whole animal and fillets with skin for different species. Toxicity Equivalents will be determined for mammals, birds and fish.

Concentrations will also be normalized to wet weight and lipid for each category (total congeners, and TEQs). For fish-consuming animals, total PCB concentrations from diet will be compared to thresholds for organisms that consume fish. An overall description of the samples collected and PCB measurements are provided in Appendix 4.

Sampling locations are provided in Figure 1.

Figure 1. Sampling locations for fish on the Spokane River in 2012.

RiverMile	River Stretch	Latitude	Longitude
28.11	SpokaneArm	47.82	-117.94
56.49	LakeSpokane	47.79	-117.53
63.99	AboveNinemile	47.72	-117.5
77.14	AboveMonroe	47.67	-117.38
96.42	AboveStateline	47.69	-117.04

Sampling locations for sediments on the Spokane River in 2013, 2015 and 2016.

RiverMile	RiverStretch	Latitude	Longitude
79.9	AboveMonroe	47.68	-117.33
79.6	AboveMonroe	47.67	-117.33
76.14	AboveMonroe	47.66	-117.39
76.22	AboveMonroe	47.66	-117.39
77.47	AboveMonroe	47.67	-117.37
79.81	AboveMonroe	47.68	-117.33
76.97	AboveMonroe	47.67	-117.38
75.62	AboveMonroe	47.66	-117.39
47.76	LakeSpokane	47.85	-117.66
36.3	LakeSpokane	47.81	-117.8

Exposure Assessment for Sediments

In order to compare sediment concentrations with fish tissue concentrations, samples from the same locations were obtained (Table 1). However, due to the inherent rocky bottom of the river, limited sediment samples were collected and all were collected after the 2005 fish collections. In addition, temporal comparisons were not possible as single site measurements were made in 2013, 2015 and 2016. Samples were normalized to dry weight for all samples, and to TOC for 2013 and 2016.

Table 1. Concentrations of total PCB (tPCB) congeners in surface sediments collected from the Spokane River.

Location	Year	Mean tPCB Concentration (ng/kg dw)	Mean TOC Content (%)	Mean tPCB TOC Normalized Concentration (ng/kg TOC)
AboveMonroe	2013	11,285	0.8	1,271,083
MidLakeSpokane	2015	16,520	NA	NA
LowLakeSpokane	2016	144,189	3.69	3,907,561

[a]Threshold for tPCBs 60,000 ng/kg

Fish tissues

Mean average tissue concentrations of total PCB congeners and TEQs normalized by wet weight and lipids are provided in Tables 2-4 for Mountain Whitefish, Large Scale Sucker, and Rainbow trout. For Mountain Whitefish PCB concentrations that were lipid normalized generally increased from above Monroe to Upper Lake Spokane. A similar trend was observed with Large Scale Sucker with the notable exception of samples collected above the Nine Mile site where concentrations were lower compared to fish from the other locations. Concentrations in Rainbow trout did not follow a trend and were unique in that they were higher at the Above Monroe sampling site compared to the other sites. Whole fish was only evaluated with Large Scale Suckers. Thus, less uncertainty for the assessment of exposure to fish consumers is present with this species. However, for Rainbow trout and Mountain Whitefish, concentrations were measured on fillets and likely underestimated exposure to consumers and to fish health in general.

Table 2. Total PCBs (tPCBs) and TEQs concentrations for Mountain Whitefish in 2012 (fillet skin on). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs (ng/kg) ww	tPCBs (ng/kg) lipid	Mam98 (ng TEQ/kg) ww	Mam05 (ng TEQ/kg) ww	TEQ Bird (ng TEQ/kg) ww	TEQ Fish (ng TEQ/kg) ww	Mam98 (ngTEQ/kg) lipid	Mam05 (ng TEQ/kg) lipid	TEQ Bird (ng TEQ/kg) lipid	TEQ Fish (ng TEQ/kg) lipid
Above Monroe	118,312[abcd]	1,744,700	4.243[e]	2.542[e]	12.252[f]	0.195	62.276	36.879	170.412	2.831
Above Nine Mile	162,782[abcd]	2,932,193#	4.938[e]	2.648[e]	12.086[f]	0.216	88.802	88.802	218.096	3.883
Upper Lake Spokane	126,011[abcd]	5,127,553#	3.682[e]	2.043[e]	8.308[f]	0.164	152.219	84.750	347.430	6.791

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)
[d]Prey threshold for fish eating organism 110,000 ng/kg ww (Newell et al., 1987)

[e]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[f]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
# Fish health threshold 2,400,000 ng/kg lipid (Meador et al. 2002)

Table 3. Total PCBs (tPCBs) and TEQs concentrations for Large Scale Sucker in 2012 (whole). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs (ng/kg) ww	tPCBs (ng/kg) lipid	Mam98 (ngTEQ/kg) ww	Mam05 (ng TEQ/kg) ww	TEQ Bird (ng TEQ/kg) ww	TEQ Fish (ng TEQ/kg) ww	Mam98 (ngTEQ/kg) lipid	Mam05 (ng TEQ/kg) lipid	TEQ Bird (ng TEQ/kg) lipid	TEQ Fish (ng TEQ/kg) lipid
Above Upriver	104,163[abc]	1,493,980	2.079[e]	0.839[e]	12.557[f]	0.110	29.310	11.392	179.801	1.557
Above Monroe	99,807[bc]	3,442,251#	2.153[e]	0.863[e]	5.067[f]	0.090	73.842	29.094	175.017	3.084
Above Nine Mile	35,218[c]	998,131	0.796[e]	0.385	2.336	0.035	21.961	10.337	66.190	0.970
Upper Lake Spokane	181,885[abcd]	7,610,037#	3.288[e]	1.275[e]	7.773[f]	0.147	130.295	46.530	331.953	5.837

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)
[d]Prey threshold for fish eating organism 110,000 ng/kg ww (Newell et al., 1987)

[e]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[f]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
# Fish health threshold 2,400,000 ng/kg lipid (Meador et al. 2002)

Table 4. Total PCBs (tPCBs) and TEQs concentrations for Rainbow trout in 2012 (fillet skin on). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs (ng/kg) ww	tPCBs (ng/kg) lipid	Mam98 (ng TEQ/kg) ww	Mam05 (ng TEQ/kg) ww	TEQ Bird (ng TEQ/kg) ww	TEQ Fish (ng TEQ/kg) ww	Mam98 (ngTEQ/kg) lipid	Mam05 (ng TEQ/kg) lipid	TEQ Bird (ng TEQ/kg) lipid	TEQ Fish (ng TEQ/kg) lipid
Above Upriver	32,319[c]	1,175,458	0.857[d]	0.468	5.067[e]	0.046	29.855	14.839	170.810	1.569
Above Monroe	100,302[abc]	6,563,237#	9.132[d]	6.990[d]	11.302[e]	0.421	753.766	600.675	809.516	35.015
Above Nine Mile	42,923[c]	1,792,634	1.077[d]	0.495	3.522[e]	0.049	46.073	21.933	149.544	2.081

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)

[d]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[e]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
# Fish health threshold 2,400,000 ng/kg lipid (Meador et al. 2002)

Effects Assessment

Tissue-based assessments:

Total PCBs

Tissue-based thresholds for adverse effects in biological organisms are provided in Table 5. All of these values used wet weight for normalizing exposures between sites and species. To assess fish health, several values were utilized. For example, the lowest effect level of mortality using early life stage values was used in earlier assessments (TAMS 2000). A more recent study by Berninger and Tillitt (2019) implemented a probabilistic species sensitivity distribution to estimate effects on mortality, growth and reproduction for fish. The lowest value for reproduction impairment (430,000 ng/kg ww) was used as a threshold. In addition, fry mortality for salmonids was also provided which would have more certainty for rainbow trout assessments (Mac&Seelye, 1981; Berlin et al., 1981).

Only one threshold was available for comparison to lipid normalized concentrations and this value used sublethal toxicity as a threshold (Meador et al. 2002). To obtain this value, 15 studies were selected that met the pre- established criteria outlined in Meador et al. (2002). For each study, the lowest tissue concentration (residue) of total PCBs associated with a biological response was selected. The tissue concentration associated with the 10th percentile of these 15 studies was chosen to represent the residue effect threshold (RET) above which wild juvenile salmonids would be expected to exhibit adverse sublethal effects from accumulated PCBs. Sublethal effects included disruptions in thyroid, immune function and growth.

With regard to fish-eating prey, several values established from numerous studies for state, provincial, and countries are provided encompassing protection for all wildlife as well as for birds and mammals. Examples of mammals in the Spokane river drainage likely to be affected by dietary exposure to PCBs due to fish consumption include black bears, raccoons, mink, and river otter. Examples of birds, include herrons, osprey, white pelicans and bald eagles. These species were determined using estimated ranges and dietary preferences provided from the Burke Museum (https://www.burkemuseum.org/; GEI 2004).

Toxicity Equivalents (TEQs)

With a focus on co-planer dioxin-like congeners, Environment Canada provided thresholds for fish eating birds/fish and fish eating mammals (Table 6). Two calculations were performed for mammals based on binding affinities for co-planar PCB congners (i.e. 126) and toxicity equivalent factors calculated initially in 1998 and re-calculated in 2005. The 1998 assessment was provided as a conservative comparison with 2005, which generally had less conservative values. Bird and fish TEQ calculations were also performed based on the relative affinities of the PCB congeners for the same receptor in birds and fish instead of mammals. Species differences occur due to different binding

affinities of PCB congeners to the Ah receptors for each organism. As mentioned above, these congeners have been shown to have significant effects on reproduction, immune function, development, and, in mammals, carcinogenicity.

Table 5. Tissue-based thresholds for ecological toxicity of total PCBs

Receptor	Concentration	Units	Type	Effect	Reference
Spiny-rayed fish/tissue	9,300,000	ng/kg ww	LOEL	Early life stage mortality	TAMS, 2000
Spiny-rayed fish/tissue	1,900,000	ng/kg ww	NOEL	Early life stage mortality	TAMS, 2000
Fish/tissue	430,000	ng/kg ww	EC20	Mortality, Growth, Reproduction	Berninger and Tillitt, 2019
Salmonids/whole body	3,000,000	ng/kg ww	LOEL	Fry mortality	Mac&Seelye, 1981; Berlin et al., 1981
Salmonids/tissue	**2,400,000**	**ng/kg lipid**	**NMFS residue effects threshold**	**Sublethal effects; thyroid/ immune/ growth/ reproduction**	**Meador et al, 2002**
Fish eating wildlife/prey	110,000	ng/kg ww	NY fish flesh criterion	Reproduction 1/100 cancer risk	Newell et al., 1987
Fish eating wildlife/prey	100,000	ng/kg ww	British Columbia guideline	Maximum to protect wildlife	BCMOELP, 1992
Fish eating avian	48,000	ng/kg ww	Environment Canada	Maximum to protect wildlife	Environment Canada, 2002
Fish eating mammal	15,000	ng/kg ww	Environment Canada	Maximum to protect wildlife	Environment Canada, 2002

Table 6. Threshold Table for TEQ analyses

Threshold	Concentration	Units	Type	Effect	Reference
Fish eating Fish/Avian TEQ	2.4	ng/kg ww	Environment Canada	Maximum to protect wildlife	Environment Canada, 2002
Fish eating Mammal TEQ	0.79	ng/kg ww	Environment Canada	Maximum to protect wildlife	Environment Canada, 2002

Sediment Assessments:

A consensus threshold derived from MacDonald et al. (2000) was used to assess risk from sediment concentrations of PCBs. A threshold based on partition coefficients was used to estimate risk when samples were normalized to TOC.

Table 7. Threshold Table for impacts on benthic invertebrates based on sediment concentrations of PCBs.

Threshold	Concentration	Units	Type	Effect	Reference
Benthic Invertebrates	60,000	ng/kg dw	Consensus	Bioassay/Benthic Community	MacDonald et al. 2000
	12,000,000	ng/kg TOC	Estimated from partition constants	Apparent Effects Threshold	(NYSDEC, 1998)

Risk Characterization

Sediment samples:

One sediment sample from the lower lake Spokane site in 2016 exceeded thresholds for total PCB concentrations normalized to dry weight (Table 7). The Hazard Quotient for that sample was 2.40. None of the samples exceeded thresholds when normalized for TOC.

Tissue samples:

When evaluated as total PCB congeners normalized by lipid, average tissue concentrations of PCBs from Mountain whitefish sampled from above Nine Mile indicated hazard as tissue concentrations exceeded thresholds for adverse effects. Large scale sucker and Rainbow trout sampled above Monroe had PCB residues exceeding thresholds, and Mountain whitefish and Large scale sucker collected from upper Lake Spokane also had concentrations of PCBs above thresholds. The significance of this

finding in Rainbow trout and Mountain whitefish is that concentrations were only measured in fillets with skin on and did not include organs such as the liver and gonads which generally have higher PCB concentrations due to high lipid content. Since PCBs are lipid soluble and partition into lipid, organisms with higher lipid concentrations tend to accumulate higher PCB levels.

Thresholds for fish eating organisms were exceeded by Mountain Whitefish PCB concentrations in all three sites. Similarly, TEQ thresholds for fish consuming mammals and birds were also exceeded.

In Large Scale Sucker, fish were collected from above Upriver in addition to the other three sites were Mountain Whitefish were collected. Average total PCB concentrations normalized for wet weight in fish did not exceed thresholds. However, when lipid normalized, PCB concentrations in Large Scale Suckers were higher in fish collected from above Monroe and in Upper Lake Spokane compared to Mountain Whitefish. Consistent with Mountain Whitefish, TEQ concentrations in Large Scale Sucker also exceeded thresholds for fish eating mammals and birds but not fish.

In Rainbow trout, total PCB concentrations normalized to wet weight did not exceed thresholds. However, when normalized to lipid, PCB concentrations were approximately 2 fold higher than Mountain Whitefish and Large Scale Sucker collected from above Monroe. This was the only sample that exceeded prey thresholds for fish eating organisms. The concentrations observed in fish from above Nile Mile only exceeded thresholds for fish eating mammals.

When using the 1998 values for TEQ calculations for mammals, all samples from Rainbow trout exceeded thresholds. However, when using the 2005 values, only samples from above Monroe exceeded threshold. TEQ values in fish from above Upriver, Monroe, and Nine Mile exceeded bird thresholds.

Summary and Conclusions:

In summary, fish collected throughout the Spokane River possessed PCB concentrations that exceeded toxicity thresholds for fish eating organisms, particularly birds and mammals. Examples of mammals that may be affected by dietary exposure to PCBs due to fish consumption include black bears, raccoons, mink, and river otter. Examples of birds that may be affected, include herrons, osprey, white pelicans and eagles.

In upper Lake Spokane, Above Nine Mile and above Monroe, concentrations of PCBs in fish indicated hazard. PCB concentrations were higher in Mountain Whitefish collected above Nine Mile, Large Scale Sucker had higher concentrations in Upper Lake Spokane, and Rainbow trout had higher concentrations above Monroe.

These data indicate hazard and elevated risks to aquatic organisms and mammalian, avian and other fish that consume fish within the Spokane River where samples were collected.

Remediation Estimates of Risk

Using models to calculate 6 concentrations in sediments following remediation, reductions below toxicological thresholds were observed in both matrices (Table 8). In sediment, concentrations of tPCBs in Lake Spokane were lowered below thresholds with each remediation scenario (Table 8).

Although fish tissue concentrations remain above threshold levels following proposed remediation, the City of Spokane reducing the amount of PCBs entering the River reduces the ecological risk posed by PCBs in the River.

Table 8. Predicted values of tPCBs in sediments before (2013-2018) and after (2030) putative remediation. Values in red were below sediment toxicity thresholds.

River Stretch	Arithmetic Mean tPCB Concentration (ng/kg dw) 2013-2018	Future Scenario 1 Highest Spokane Treatment; Lower Bound Loads Other Sources	Future Scenario 2 Highest Spokane Treatment; Upper Bound Loads Other Sources	Future Scenario 3 Mid-level Spokane Treatment; Lower Bound Loads Other Sources	Future Scenario 4 Mid-level Spokane Treatment; Upper Bound Loads Other Sources	Future Scenario 5 Lowest Spokane Treatment; Lower Bound Loads Other Sources	Future Scenario 6 Lowest Spokane Treatment; Upper Bound Loads Other Sources
AboveMonroe	22,840	9,165	9,364	9,165	9,364	9,166	9,364
LakeSpokane	80,354	38,044	43,409	39,210	43,957	39,301	44,000

Table 9. Predicted values of tPCBs normalized to wet weight in fish before (2012) and after (2018/2030) putative remediation.

Common Name	River Stretch	Arithmetic Mean tPCB Concentration (ng/kg ww) 2012	Future Scenario 1 2018	Future Scenario 2 2018	Future Scenario 1 Highest Spokane Treatment; Lower Bound Loads Other Sources 2030	Future Scenario 2 Highest Spokane Treatment ; Upper Bound Loads Other Sources 2030	Future Scenario 3 Mid-level Spokane Treatment ; Lower Bound Loads Other Sources 2030	Future Scenario 4 Mid-level Spokane Treatment ; Upper Bound Loads Other Sources 2030	Future Scenario 5 Lowest Spokane Treatment ; Lower Bound Loads Other Sources 2030	Future Scenario 6 Lowest Spokane Treatment ; Upper Bound Loads Other Sources 2030
Largescale Sucker	AboveMonroe	99,807	101,820	101,308	100,517	100,507	100,517	100,507	100,518	100,507
Largescale Sucker	AboveNinemile	35,218	34,753	35,190	32,676	33,620	32,697	33,634	32,698	33,634
Largescale Sucker	LakeSpokane	181,885	179,499	181,753	168,827	174,210	168,936	174,277	168,941	174,280
Mountain Whitefish	AboveMonroe	118,312	120,699	120,092	119,154	119,142	119,154	119,142	119,155	119,142
Mountain Whitefish	AboveNinemile	162,782	160,635	162,655	151,034	155,396	151,132	155,461	151,137	155,464
Mountain Whitefish	LakeSpokane	126,011	124,358	125,919	116,964	120,693	117,039	120,740	117,043	120,742
Rainbow Trout	AboveMonroe	100,302	102,325	101,810	101,015	101,005	101,015	101,005	101,016	101,005
Rainbow Trout	AboveNinemile	42,923	42,356	42,889	39,825	40,975	39,851	40,992	39,852	40,993

Table 10. Predicted values of tPCBs normalized to lipid in fish before (2012) and after (2018/2030) putative remediation.

Common Name	River Stretch	Arithmetic Mean tPCB-Lipid Normalized Concentration (ng/kg lipid) 2012	2018 Scenario 1	2018 Scenario 2	Future Scenario 1 Highest Spokane Treatment; Lower Bound Loads Other Sources 2030	Future Scenario 2 Highest Spokane Treatment; Upper Bound Loads Other Sources 2030	Future Scenario 3 Mid-level Spokane Treatment; Lower Bound Loads Other Sources 2030	Future Scenario 4 Mid-level Spokane Treatment; Upper Bound Loads Other Sources 2030	Future Scenario 5 Lowest Spokane Treatment; Lower Bound Loads Other Sources 2030	Future Scenario 6 Lowest Spokane Treatment; Upper Bound Loads Other Sources 2030
Largescale Sucker	AboveMonroe	3,442,251	3,511,700	3,494,035	3,466,746	3,466,388	3,466,746	3,466,388	3,466,770	3,466,403
Largescale Sucker	AboveNinemile	998,130	984,967	997,351	926,099	952,844	926,700	953,241	926,726	953,258
Largescale Sucker	LakeSpokane	7,610,037	7,510,194	7,604,512	7,063,680	7,288,908	7,068,240	7,291,722	7,068,439	7,291,845
Mountain Whitefish	AboveMonroe	1,744,700	1,779,900	1,770,947	1,757,115	1,756,934	1,757,115	1,756,934	1,757,127	1,756,941
Mountain Whitefish	AboveNinemile	2,932,193	2,893,524	2,929,904	2,720,587	2,799,156	2,722,353	2,800,322	2,722,430	2,800,373
Mountain Whitefish	LakeSpokane	5,127,553	5,060,281	5,123,831	4,759,425	4,911,180	4,762,497	4,913,077	4,762,631	4,913,160
Rainbow Trout	AboveMonroe	6,563,237	6,695,654	6,661,973	6,609,942	6,609,259	6,609,942	6,609,259	6,609,987	6,609,287
Rainbow Trout	AboveNinemile	1,792,634	1,768,993	1,791,234	1,663,265	1,711,300	1,664,345	1,712,012	1,664,392	1,712,044

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Appendix 1.

Hazard Quotients for Total PCBs (tPCBs) and TEQs concentrations for Mountain Whitefish in 2012 (fillet skin on). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs ww	tPCBs lipid	TEQ Mam98	TEQ Mam05	TEQ Bird	TEQ Fish
Above Monroe	1.2[a] 2.5[b] 7.9[c] 1.1[d] 0.28*	0.72#	5.3[e]	3.2[e]	5.2[f]	0.081[f]
Above Nine Mile	1.6[a] 3.4[b] 10.9[c] 1.5[d] 0.38*	1.2#	6.3[e]	3.4[e]	5.0[f]	0.090[f]
Upper Lake Spokane	1.3[a] 2.6[b] 8.4[c] 1.1[d] 0.29*	2.1#	4.7[e]	2.6[e]	3.5[f]	0.068[f]

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)
[d]Prey threshold for fish eating organism 110,000 ng/kg ww (Newell et al., 1987)

[e]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[f]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
 # Fish health threshold 2,400,000 ng/kg lipid (Meador 2000)

Appendix 2 Hazard Quotients for Total PCBs (tPCBs) and TEQs concentrations for Large Scale Sucker in 2012 (whole). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs (ng/kg) ww	tPCBs (ng/kg) lipid	Mam98 (ngTEQ/kg) ww	Mam05 (ng TEQ/kg) ww	TEQ Bird (ng TEQ/kg) ww	TEQ Fish (ng TEQ/kg) ww
Above Upriver	1.0[a] 2.2[b] 6.9[c] 0.95[d] 0.24[*]	0.62[#]	2.6[e]	1.1[e]	5.2[f]	0.046[f]
Above Monroe	1.0[a] 2.1[b] 6.7[c] 0.91[d] 0.23[*]	1.4[#]	2.7[e]	1.1[e]	2.1[f]	0.038[f]
Above Nine Mile	0.35[a] 0.73[b] 2.3[c] 0.32[d] 0.082[*]	0.42[#]	1.0[e]	0.49[e]	0.97[f]	0.016[f]
Upper Lake Spokane	1.8[a] 3.8[b] 12.1[c] 1.7[d] 0.42[*]	3.2[#]	4.2[e]	1.6[e]	3.2[f]	0.061[f]

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)
[d]Prey threshold for fish eating organism 110,000 ng/kg ww (Newell et al., 1987)

[e]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[f]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
# Fish health threshold 2,400,000 ng/kg lipid (Meador 2000)

Appendix 3. Hazard Quotients for total PCBs (tPCBs) and TEQs concentrations for Rainbow trout in 2012 (fillet skin on). Mam98 is the TEQ calculation for mammals from 1998 and Mam05 is the TEQ calculation from 2005.

Site	tPCBs (ng/kg) ww	tPCBs (ng/kg) lipid	Mam98 (ng TEQ/kg) ww	Mam05 (ng TEQ/kg) ww	TEQ Bird (ng TEQ/kg) ww	TEQ Fish (ng TEQ/kg) ww
Above	0.32[a]	0.49#	1.1[e]	0.59[e]	2.1[f]	0.019[f]
Upriver	0.67[b]					
	2.2[c]					
	0.29[d]					
	0.075*					
Above	1.0[a]	2.7#	11.6[e]	8.8[e]	4.7[f]	0.18[f]
Monroe	2.1[b]					
	6.7[c]					
	0.91[d]					
	0.23*					
Above	0.42[a]	0.75#	1.077[e]	0.63[e]	1.5[f]	0.020[f]
Nine Mile	0.89[b]					
	2.9[c]					
	0.39[d]					
	0.10*					

[a]Prey threshold for fish eating organism 100,000 ng/kg ww (BCMOELP 1992)
[b]Prey threshold for fish eating avian 48,000 ng/kg ww (Environment Canada 2002)
[c]Prey threshold for fish eating mammal 15,000 ng/kg ww (Environment Canada 2002)
[d]Prey threshold for fish eating organism 110,000 ng/kg ww (Newell et al., 1987)

[e]Prey TEQ threshold for fish eating mammal 0.79 ng/kg ww (Environment Canada 2002)
[f]Prey TEQ threshold for fish eating fish/avian 2.4 ng/kg ww (Environment Canada 2002)

* Fish health threshold 430,000 ng/kg ww (Berninger and Tillitt 2019)
# Fish health threshold 2,400,000 ng/kg lipid (Meador 2000)

Appendix 4. Methodology for Exposure Assessment.

Technical Memorandum

Data Analysis Methods for Risk Assessment Summaries: PCB Concentrations in Spokane River Fish Tissues

Date: June 18, 2019

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USE & LIMITATIONS OF THIS MEMORANDUM

This technical memorandum has been prepared by Azimuth Consulting Group Partnership ("Azimuth") for the use of Baron & Budd, P.C. (Baron & Budd P.C.; the "Client"). The Client has been party to the development of the scope of work for the subject project and understands its limitations.

The Client agrees, by accepting this memorandum, that in providing this memorandum and performing the services in preparation of this memorandum Azimuth accepts no responsibility in respect of the Spokane River study area described in this memorandum or for any business or legal decisions made by the Client in reliance on this memorandum.

This memorandum is intended to document the methods used by Azimuth to summarize and analyze data on polychlorinated biphenyl (PCB) concentrations in fish tissues from the Spokane River. Summary tables and figures are provided separately for the use of the Client; data interpretation, conclusions and recommendations are not contained herein.

Any use of, reliance on, or decision made by a third party based on this memorandum (other than Baron & Budd and its experts engaged for the purposes of the Action related to Baron & Budd's representation of entities with regards to PCB contamination in the Spokane River), or the services performed by Azimuth in preparation of this memorandum is expressly prohibited, without prior written authorization from Azimuth. Without such prior written authorization, Azimuth accepts no liability or responsibility for any loss, damage, or liability of any kind that may be suffered or incurred by any third party as a result of that third party's use of, reliance on, or any decision made based on this memorandum or the services performed by Azimuth in preparation of this memorandum.

The information contained in this memorandum are based, in part, upon information provided by others (i.e., a project database provided by other parties retained by Baron & Budd). While Azimuth has reviewed some of the data contained in the database for accuracy, in preparing this memorandum, Azimuth has assumed that the data or other information provided by others is factual and accurate. If any of the information is inaccurate, conditions of the study area change, new information is discovered, and/or unexpected conditions are encountered in future work, then modifications by Azimuth to the information reported in this memorandum may be necessary.

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1. OVERVIEW

This technical memorandum documents the methods used to summarize and analyze data on polychlorinated biphenyl (PCB) concentrations in fish and crayfish ("fish") tissues collected from the Spokane River.

A project database was received from Baron & Budd P.C. ("Baron & Budd"; the "Client") and served as the basis for the data summary and analysis. The data analysis was supported by a literature review, which focused on publications by the Washington State Department of Ecology ("Ecology"), LimnoTech for the Spokane River Regional Toxics Task Force (SRRTTF), City of Spokane, as well as other relevant documents and information (fish study references relevant to this memorandum are provided in Section 6 - References).

Steps involved in the analysis included data clean-up and filtering, data treatment and calculations, preparation of summary tables and figures, and quality assurance/quality control (QAQC) review. This memorandum includes the following sub-sections:

1. Overview
2. Source Database
3. Dataset Preparation
4. Calculations
5. Data Summary Packages
6. References

This memorandum specifically supports risk assessment summaries provided in fish data packages versions 3 and 4 (provided to the Client separately). This document does not include results, interpretation, conclusions or recommendations.

2. SOURCE DATABASE

2.1. Description

A database was received from Baron & Budd for the project (version 13, April 04, 2019). We note that, while the database has been updated since version 13, recent versions primarily contain updates to the Spokane River PCB water data, with no new or updated fish data. The latest version of the database (version 18, June 11, 2019) contains periphyton and invertebrate tissue data (Wong and Era-Miller 2019a, Wong and Era-Miller 2019b, Wong and Era-Miller 2019c); given these data are not being used for the risk assessments, the updated version 18 database is not required.

The database was prepared by the Client's consultants, Pacific Groundwater Group (PGG) and delivered in two file formats:

1. Spokane PCB Database v13.accdb (Access database) – this file was not directly used in the data analysis; an Export Query file was used (see below). The Access version contained several tables with various fields of information. Data tables in Access were reviewed, as needed.
2. ExportQuery-v13.csv (comma-separated value; "csv") – csv export file from Access. A minor modification (related to one sediment study, so not described herein) was made by Azimuth to the original csv file and then saved as "ExportQuery-v13r.csv". This file was used in the fish data analysis.

A description of the fields contained in ExportQuery-v13r.csv file is shown in Table A (from PGG with edits by Azimuth). Additional fields are contained within the Access database.

Table A: Fields (column headers) and descriptions contained in the Spokane River PCB project database export file.

Field	Definition
StudyID	Department of Ecology (or other entity) study ID code
txtStationID	Name of sample collection location
Location	Secondary location name/description
River	River sample was collected from; used if sample was collected in or adjacent to a river
RiverMile	River mile of location sample was collected from
Latitude	Location coordinates - latitude
Longitude	Location coordinates - longitude
txtSampleID	Name of sample, may be assigned by sampler or lab
dtmSampleDate	Date sample collected on
CollectionMethod	Method used for collecting sample
UpperDepth	Upper depth of soil/sediment sample
LowerDepth	Lower depth of soil/sediment sample
DepthUnit	Depth unit of soil/sediment sample
TaxonName	Scientific name of species or taxon (e.g., family) for tissue samples
CompositeFlag	Flagged "y" if sample is a composite of multiple samples (e.g., individual fish, multiple sediment grabs); "n" if not
Data Source	Entity providing data (e.g., City of Spokane)
ResultTaxonName	Taxon if broken out by result (not filled in)
TissueType	Tissue type of fish analyzed for PCB or other paramater (e.g., whole organism; fillet, skin on)
AnalysisMethod	Method of chemical analysis used by laboratory
Matrix	General media type (e.g., water, sediment, tissue)
Sample Source	Sub category of media type (e.g., cap sand, freshwater sediment, effluent, groundwater)
LabReplicateFlag	A replicate sample split in the laboratory
SampleReplicateFlag	Separate samples collected as close as possible to the same point in space and time as the originals. In the case of tissues, is from the same fish/composite group as the original.
FractionAnalyzed	Total or dissolved fraction for water samples
QAFlag	Flag for blank, duplicate, spike samples (generally not filled in)
Result_Basis	Whether concentration is on a wet weight or dry weight basis
Constituent	Analyte (e.g., PCB constituent or supporting measurement)
dblLimit	Detection limit
Result	Value (i.e., concentration)
txtUnits	Units of measure for result
txtQual	Qualifier (e.g., identifies results that are "U" = less than detection limit or "J" = estimated)
CountOfAnalyses	Number of analytes in Project Summed Constituents (e.g., number of congeners or Aroclors summed for total PCBs)
CountOfNDs	Number of non-detect values in Project Summed Constituents
dblBlankResult	Concentration of constituent in blank sample (water data only)
txtResult>3xBlankFlag	"Yes" if PCB sample measurement is above the blank; "no" if not (water data only)
txtBlankCensorNote	Note added by PGG regarding blank censoring (water data only)

The database includes PCB concentration data for various media (e.g., surface water, effluent, sediment, biota tissues, etc.). Original data were imported into the project database from various sources, with the fish tissue data exclusively derived from Washington State's Department of Ecology (Ecology) Environmental Information Management System (EIM) database.

All PCB fish tissue concentration data were in units of ng/kg wet weight. Lipid contents (%) were included in the database and used in the analyses described in this document. Other fish tissue supporting data (e.g., fish weight and length) have not been included in the data summaries or analyses. PCB constituents in the database include individual Aroclors and PCB congeners. As well, for all types of media, the database included calculations of total PCB (tPCB) concentrations (labelled "tPCB Aroclors…" or "tPCB Congeners…"). tPCBs were calculated as the sum of all the PCB Aroclors or congeners/co-eluters measured in a sample. tPCB concentrations were often not included in the EIM database because there are different ways to calculate tPCBs, depending on the assumption used for PCB congeners or Aroclors that were less than the analytical detection limit[1] (also referred to as "non-detect" data). PCB results that are less than detection are denoted in the Access database with a "U" flag (including U variants such as U, UG, UJ, NUJ) in the field "txtQual". Data qualifier flags contained in tissue dataset are shown in Table B, with a more complete list for the EIM database provided in EIM reference materials (Ecology 2018).

[1] The Access database has a "LimitType" field which identifies the type of detection limit reported. Some of the main categories of detection limits include (see EIM database reference material [Ecology, 2018]):

- MRL - Method Reporting Limit
- PQL - Practical Quantitation Limit
- EQL - Estimated Quantitation Limit
- LOQ - Limit of Quantitation
- SQL - Sample Quantitation Limit

Table B: Data qualifier flags[§] contained in the biota tissue dataset.

	ition
	eeds" - The concentration exceeds the known calibration range.
	nated" - The analyte was positively identified; the associated numerical value is the ximate concentration of the analyte in the sample.
	ative" - There is evidence the analyte is present in this sample; tentatively identified te.
	ative Estimate" - The analyte has been tentatively identified and the associated numerical represents its approximate concentration.
	etected at Estimated Limit for Tentative Analyte" - There is evidence the analyte is present sample. Tentatively identified analyte was not detected at or above the reported estimate.
	sable" - The data are unusable for all purposes. Sample results rejected due to serious encies in the ability to analyze the sample and meet quality control criteria. The presence sence of the analyte cannot be verified.
	etected" - The analyte was not detected at or above the reported sample quantitation limit.
	etected at Estimated Limit" – The analyte was not detected at or above the reported sample itation limit. However, the reported quantitation limit is approximate.

[§]References used include (Serdar and Johnson 2006, Era-Miller 2015, Ecology 2018).
*No REJ flags in tissue samples from the Spokane River.

In the project database, three approaches were used for the tissue data to determine tPCBs (C_{tPCB}, ng/kg wet weight) when the measurement of individual PCB constituent concentrations ($C_{PCB(n)}$, ng/kg wet weight) was less than the detection limit:

1. "tPCB Congeners/Aroclors – LimitZero" – Individual congeners or Aroclors that were less than the detection limit were assigned zero in the summation of tPCBs:

Equation 1

$$C_{tPCB\ (congeners)} = \sum_{n=1}^{209} C_{PCB(n)}$$

Where congeners/Aroclors that were less than the detection limit (i.e., "txtQual" contained a "U" variant) were substituted by zero.

2. "tPCB Congeners/Aroclors - Limit/2" – Individual congeners or Aroclors that were less than the detection limit, were assigned one-half the detection limit in the summation of tPCBs:

   See Equation 1
   Where congeners/Aroclors that were less than the detection limit (i.e., "txtQual" contained a "U" variant) were substituted by one-half the detection limit.

3. "tPCB Congeners/Aroclors - Limit" – Individual congeners or Aroclors that were less than the detection limit, were assigned the full detection limit in the summation of tPCBs:

   See Equation 1
   Where congeners/Aroclors that were less than the detection limit (i.e., "txtQual" contained a "U" variant) were substituted by the full detection limit.

All three of these methods are considered common approaches to calculate tPCBs from congener or Aroclor results and provide a range of uncertainty in the estimate of tPCB concentrations. Note that the third treatment using the full detection limit was only used in some of the data summaries, where requested by Experts.

2.2. Review of Tissue Dataset in Database

Quality assurance/quality control (QA/QC) review of the tissue data contained in the project database was conducted on all database versions. After reviews of earlier versions, information was added to the database to support data analysis (e.g., supporting parameters added; the spatial coverage was expanded to include data throughout the entire Spokane River; and the fields "River" and "RiverMile" were added to spatially locate samples in the Spokane River based on latitude and longitude entries for sample stations). The database was cross-checked with data reported in original studies for accuracy and completeness by Azimuth (e.g., tPCB Congeners/Aroclors – LimitZero were spot-checked with tPCBs reported in Ecology studies; ancillary data was checked for entry and completeness in the database; tPCBs were recalculated for a few samples; other information such as species, tissue types and location details were checked). All issues identified with the data were corrected.

For the tissue dataset, two changes were made to the project database, related to errors or omissions in the original EIM database (identified by cross-checks against Ecology reports):

- For study AJOH0005, two largescale sucker (*Catostomus macrocheilus*) fish samples that were collected from the Spokane River in Idaho were added to the database for completeness (Sample IDs: 94328435 and 93318244; data transcribed into Excel by Azimuth).

- For study AJOH0022 and sample ID 99485018, an incorrect taxon name was entered into EIM for the Aroclor results only (not congener results); *Oncorhynchus mykiss* was corrected to *Catostomus macrocheilus*.

While there were no other changes made to tissue data in the project database, Azimuth made another correction during data analysis (see also Section 3):

- The tissue type of crayfish sample 94318265 in study AJOH0005 was designated "Whole organism (animal)" in the EIM database. This appeared erroneous as all other samples collected during the program were designated as "Muscle" in EIM and crayfish samples were designated by Ecology as "Muscle" or "Fillet" in their reports (Davis and Serdar 1994, Johnson 1994a, Ecology 1995). The tissue type for this sample was therefore changed to "Muscle" in the analysis code.
- Other tissue types were re-labelled in the analysis code to keep naming conventions consistent between studies (see Section 3).

3. DATASET PREPARATION

R statistical computing software version 3.5.1 (2018-07-02) - "Feather Spray" was used for the data analysis. An R script (programing code) was developed in R Markdown (rmd) format and run in R Studio.
The following steps were conducted in R:

1. Cleaned-up and set-up the workspace for data analysis. These steps included:

a) Clearing workspace of any previously loaded objects,

b) Setting the working directory – directing the software to the folder containing source files necessary for the code to run properly, including the R scripts and data,

c) Installing and loading software packages (designed to accomplish various analytical tasks in R) required for the data analysis. Packages used for this project include:

- tidyverse (data wrangling and organization, includes ggplot for creating graphs),
- lubridate (working with dates),
- knitr (converting rmd script to PDF),
- evaluate (parsing and evaluating tools)
- ggmap (creating maps),
- ggrepel (keeping text labels away from each other).

2. Imported data files – loaded the ExportQuery-v13r.csv data file.

3. Formatted variable columns – reviewed import files to ensure that the data were in the proper format. Examples of this include:

a) Reformatted dates to be consistent between studies,

b) Used lower case formatting for data entries (e.g., "TISSUE", "Tissue", and "tissue" were all changed to "tissue"),

c) Inspected variable classes and set these to the correct format (e.g., character, numeric, logical).

4. Subset dataset – selected relevant data columns and rows/samples by filtering for the following conditions:

a. Tissue data only (i.e., subset to Matrix = Tissue).

b. Data collected from within the Spokane River itself, excluding tributaries (e.g., River = Spokane River).

c. Removed studies containing only ancillary parameters (e.g., lipids or fish length and weight) without paired PCB data. These data were generally from studies on other contaminants, such as mercury, in the Spokane River.

d. Carried forward constituents that were used in the analysis:

i. tPCB results (based on Aroclors, congeners, using the full limit, half limit, zero limit treatments);

ii. Ancillary data (e.g., lipids, fish length and weight). Note "Non-polar lipids" was dropped as a constituent because there were only two samples and both had regular lipid analysis conducted;

iii. 12 dioxin-like PCB congeners, as designated by the World Health Organization (WHO), were carried forward for reporting individual congener concentrations and for the calculation of Toxic Equivalencies (TEQs)[2]. These congeners include non-ortho substituted PCBs: PCB-077, PCB-081, PCB-126, and PCB-169, and mono-ortho substituted PCBs: PCB-105, PCB-114, PCB-118, PCB-123, PCB-156, PCB-157, PCB-167, and PCB-189, as well as any co-eluters.

iv. Seven individual congeners associated with Non-Hodgkin's Lymphoma (NHL) were also retained in the dataset for reporting individual congener concentrations: PCB-118*, PCB-138, PCB-153, PCB-156*, PCB-170, PCB-180, PCB-187, as well as any co-eluters. (*Starred congeners are also in the dioxin-like list above).

v. Individual Aroclors were retained for reporting Aroclor concentrations: PCB-Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268.

e. Removed unnecessary columns to limit dataset to tissue-specific information (e.g., dropped Collection Method, Upper Depth, Lower Depth, and Fraction Analyzed, etc.).

Based on these selection criteria, the full list of studies containing PCB concentration data in fish of the Spokane River is shown in Table C, which corresponds to studies identified as having relevant data in the literature review.

Table C: Study IDs, years sampled and references included in the Spokane River fish tissue dataset.

' ID	ence(s)
I0005	s and Serdar 1994, Ecology 1995)
I0005	son 1994a, Ecology 1995)

[2] TEQs were not calculated for the 1999 study AJOH0022 because only 23 PCB congeners were analyzed and three of the dioxin-like PCBs: PCB-123, -167, -189 were not included. As a result, TEQ values may be underestimated. This study ended up being filtered out of the risk assessment analysis, as it was from an earlier time period and not considered representative of current or recent conditions.

' ID	ence(s)
10008	son 1997)
10022	son 2000)
A0011	Miller 2015)
R0002	ar, Johnson et al. 1994)
R0010	ar, Lubliner et al. 2011)
R0010	ar, Lubliner et al. 2011)
R0016	ar and Johnson 2006)
R0003	ig 2018)
002	and Roose 2002)
MP93T	s, Johnson et al. 1995)
MP03T	ar, Lubliner et al. 2011)
MP12	ers, Deligeannis et al. 2014)

Note, Washington Department of Ecology/U.S. EPA studies (Joy 1984) and (Johnson 1994b) were not entered by Ecology into the EIM database and were, therefore, not included in this analysis. These studies are older and not considered representative of recent or current conditions.
The risk assessment analysis focused on specific studies/years, so only a subset of the above studies was used to develop the data summaries (see bullet #7 below).

5. Cleaned-up sample duplicates – additional data filtering was required to ensure samples were not double counted in the dataset:

a. Sample replicates were dropped from the analysis (corresponding to Sample Replicate Flag = Y), to avoid double counting these samples.

b. For samples where both congeners and Aroclors were measured, code was added to preferentially select congener data over Aroclor[3], so that single samples would not be double counted in the dataset.

In the version 4 data package, all duplicate tPCB by Aroclors were dropped. This package focused on recent studies and included a conversion of tPCB by Aroclor to "tPCB congener equivalent" (described in Section 4). Summary tables show pooled tPCB congener and tPCB congener equivalent data. Note that in versions 2 and 3 of the fish data package, both tPCB by Aroclor and tPCB by congener were retained but kept as separate line items in the risk assessment summary tables. This specifically applied to the 2012 WSTMP12 fish study, where some samples were analyzed by both congener and Aroclor methods. At the request of the Expert, duplicate tPCB Aroclor results were not dropped from the summary tables but were reported separately from tPCB congener results.

[3] In study AJOH0022 (1999 data), only 23 congeners were analyzed, and therefore the tPCB concentration by congener analysis was much lower than tPCB by Aroclor analysis and is considered an underestimate of tPCBs. Thus, tPCB Aroclor results were retained and tPCB congener results were dropped for this study. This study was not used for the risk assessment summaries.

c. Within the tissue dataset, multiple fish tissue types were used for PCB analysis, varying by species of fish/crayfish and by study (e.g., fillet, skin on; fillet, skin off; whole organism (animal)). All categories were reviewed to determine how to best group the data, with emphasis on characterizing the less common tissue types (e.g., whole organism, not fillets). As a result, certain tissue types were dropped; others were corrected or relabeled. As well, it was noted that, in some cases, multiple tissue types were analyzed for the same fish or composite sample; these were cleaned-up in the data analysis to ensure that the same fish/composite was not double counted in the summary statistics. The following summarizes the main "tissue type" changes that were made in the dataset (see also Table D):

a. Tissue type "gut contents" was dropped.

b. There were multiple tissue types analyzed for the same fish/composite sample in a few cases in studies DSER0016 and WSTMP12. The "Whole organism, not fillets" (or carcass) samples were dropped, with "Fillet, skin on" or "Whole organism (animal)" being retained, depending on fish species and study (see notes at bottom of Table D).

c. Re-labelling of tissue types was done to use consistent naming conventions and enable proper grouping of data. All changes were based on a review of the original studies and are described in Table D.

d. Based on corrections and relabeling, the following tissue types were included in the final tissue dataset:

i. Fillet, skin on;

ii. Fillet, skin off;

iii. Whole;

iv. WholeCRF (only for crayfish);

v. Muscle (only for crayfish).

Table D: Tissue type categories for the biota tissue dataset.

No.	Original Tissue Type	Study ID	Species [1]	Notes on Changes to Tissue Type Designation in R Dataset
1	Fillet, skin on [2]	AJOH0005	SMB, LMB, RBT, KOK, YP, WCP, MWF, NPM, BRT, WAL	
		AJOH0008	RBT, MWF	
		AJOH0022	LSS, RBT, MWF	
		DSER0010	RBT	
		DSER0016	BLS, SMB, RBT, MWF, BRT	
		RJAC002	LSS, SMB, LMB, YP, MWF	
		WSTMP03T	RBT	
		WSTMP12	LSS, RBT, MWF, NPM, BRT	
2	Fillet portion (epaxial muscle), skin off [3]	DSER0002	LMB, YP	
	Tissue type 2 relabeled as "Fillet, skin off"	WSPMP93T	RBT	
3	Muscle [4]	AJOH0005	CRF	
		DSER0010	CRF	Tissue type for DSER0010 CRF was relabeled "Muscle" (originally Type 5)
4	Whole organism (animal) [5a]	AJOH0005	~~CRF,~~ LSS	CRF tissue type changed to "Muscle" [5b, Ref a, b, c]
	Tissue type 4 relabeled as "Whole"	AJOH0008	LSS	
		AJOH0022	LSS, RBT, MWF, ~~CRF~~	CRF tissue type relabelled to "WholeCRF"
		BERA0011	CCP	
		DSER0002	LSS	
		DSER0010	BLS, LSS	
		DSER0016	BLS, LSS, RBT, MWF	
		mifr0003	RBT	
		RJAC002	LSS	
		WSPMP93T	LSS	
		WSTMP12	LSS	
5	Whole organism, not exoskeleton or shell, not gut [6a]	~~DSER0010~~	~~CRF~~	CRF tissue type relabelled "Muscle" [6b, ref e]
	Tissue type not carried forward			
6	Whole organism, not fillets [7]	~~DSER0016~~	~~BLS, RBT, MWF~~	Multiple tissue types; this type not carried forward [7]
	Tissue type not carried forward	~~WSTMP12~~	~~LSS~~	Multiple tissue types; this type not carried forward [7]
7	Added tissue type 7 "WholeCRF"	AJOH0022	CRF	Tissue type for AJOH0022 CRF was relabeled "WholeCRF" (originally Type 4)

Table Notes:

~~Strikethrough~~ - denotes tissue type changed or relabelled.

[1] See species list in Note 5 for corresponding common and scientific names.

[2] Slime and scales removed and then rinsed with tap and then deionized water. Fish then filleted with skin left on and homogenized. [Ref g, h]

[3] Muscle tissue samples prepared by compositing ~40 g of skinless epaxial muscle from each individual fish. [Ref f] Tissue type renamed "Fillet, skin off"

[4] Abdominal (tail) muscle. [Ref a]

[5a] Ageing structures removed and remaining whole organism homogenized. [Ref g, h] Tissue type renamed "Whole".

[5b] Tissue type designation of CRF Sample ID: 94318265 in AJOH0005 appears erroneous in the EIM database; all other samples collected during the program designated as "muscle"; data reported by Ecology as "muscle" or "fillet" [Ref a, b and d]; "Whole organism (animal)" changed to "Muscle".

[6a] Corresponds to "tail muscle" i.e., the entire tail muscle (4-5 g) was removed from the exoskeleton and homogenized. [Ref e]

[6b] CRF Sample ID: 4208148 in DSER0010 reported as "tail muscle" [Ref k] (i.e., tissue type is the same as "Muscle", but was named differently in the EIM database).

[7] Corresponds to carcass (skin, bone, remaining soft tissues); fillets were removed and analyzed separately. Carcass samples were dropped as other tissue types were available for these fish:
DSER0016: BLS weighted whole body average data used "Whole" for Sample ID 05424257-05424258 (Dropped carcass and fillet samples: 5424257 and 5424258)
DSER0016: RBT fillet data used "Fillet, skin on" for Sample ID 5494272 (Dropped carcass and whole samples: 5524719 and 05494272-05524719)
DSER0016: MWF fillet data used "Fillet, skin on" for Sample ID 5494271 (Dropped carcass and whole samples: 5524718 and 05494272-05524719)
WSTMP12: LSS fillet data used "Fillet, skin on" for Sample ID 1301011-96 (Dropped carcass sample: 1301011-48; whole not available)

Table References

[a] Ecology (Washington Department of Ecology). 1995. Department of Ecology 1993-94 Investigation of PCBs in the Spokane River. Washington State Department of Ecology. Olympia, WA.

[b] Davis, D., Serdar, D. 1994. Results of 1993 screening survey on PCBs and Metals in the Spokane River (with corrections). Washington State Department of Ecology. Olympia, WA.

[c] Johnson, A. 1994(a). Planar PCBs in Spokane River Fish. Toxics, Compliance, and Ground Water Investigations Section - Washington State Department of Ecology. WA.

[d] Johnson, A. 1994(b). PCB and Lead Results for 1994 Spokane River Fish Samples. Toxics Investigation Section - Washington State Department of Ecology. WA.

[e] Serdar, D., Lubliner, B., Johnson, A., Norton, D. 2011. Spokane River PCB Source Assessment 2003-2007. Washington State Department of Ecology. Olympia, WA.

[f] Serdar, D., Johnson, A., Davis, D. 1994. Survey of Chemical Contaminants in Ten Washington Lakes.

[g] Serdar, D., Johnson, A. 2006. PCBs, PBDEs, and Selected Metals in Spokane River Fish, 2005. Washington State Department of Ecology. Olympia, WA.

[h] Serdar, D. 2013. Quality Assurance Project Plan: Freshwater Fish Contaminant Monitoring Plan. Washington State Department of Ecology. Olympia, WA.

6. Added identifier columns – to enable grouping data by various categories, several columns were added, including:

a. "AnalysisType" was added to classify constituents as:

e. Aroclor – individual Aroclor parameters (see Section 4 for calculations by limit type),

f. Congener – individual congener parameters (see Section 4 for calculations by limit type),

g. Supporting – ancillary data (e.g., lipid content, fish length and weight),

h. TEQ – calculated TEQs (see Section 4),

i. Sum Aroclors – sum of individual Aroclors for tPCB calculation (see Section 2.1 for detection limit treatments in the database) [summaries provided in version 3 data package],

j. Sum Congeners – sum of individual congeners for tPCB calculation (see Section 2.1 for detection limit treatments in the database),

k. Sum Congeners Equivalent – tPCB measured by Aroclor converted to congener equivalents (see Section 4).

b. "LimitType" assigned PCB constituents as "Zero", "Half" or "Full" (corresponding to the tPCB treatments shown in Section 2.1 or Section 4 for other parameters). The "Full" limit was only used in some data summaries, where requested.

c. A "RatioNDs" column calculated for tPCB constituents as the ratio between the "CountOfNDs" (number on non-detect congeners/Aroclors comprising tPCBs) to the overall "CountOfAnalyses" (total number of congeners/Aroclors comprising tPCBs).

d. Date specifier columns were also added to group data by "Year" or "Decade".

e. In version 4, scenario columns were added to categorize data as "Baseline" or "Current", and select relevant studies representing years of interest. The following options were provided for these scenarios:

l. Baseline scenario (2005 only) – includes DSER0016 (2005) only,

m. Baseline scenario (2001-2005) – the key study was DSER0016 (2005), supplemented with data from RJAC002 (2001), WSTMP03T (2003), DSER0010 (2003/2004),

n. Current scenario (2012 only) – included WSTMP12 (2012) only.

f. A "RiverStretch" column was added to assign samples based on River Mile according to compartments that have been designated for the project. The "RiverStretch" categories are generally split by dam locations in the Spokane River, the exceptions being that the Stateline is used rather than Post Falls

Dam and there was an additional split between the upper and lower portions of Lake Spokane for the risk assessment summaries Error! Reference source not found..

Table E: River stretches used for the biota tissue dataset for the risk assessment summaries.

Stretch	Miles
eStateline	12-96.1
eUpriver	⁾6.1-80.2
eMonroe	;0.2-74.0
eNinemile	'4.0-58.1
:Spokane	;8.1-46.0
.kSpokane	;6.0-33.9
eLittleFalls	;3.9-29.3
aneArm	;9.3-0

g. "TaxonName" – this column was originally in the database and contained the Latin names of species collected in the Spokane River studies (although crayfish was sometimes identified by family name only). Additional identifier columns were added to group or display species by "CommonName", "SpeciesCode", and "TaxonGroup". "TaxonGroup" was used for graphing to separate out the species that were most commonly (or recently) collected in the Spokane River: Rainbow Trout, Mountain Whitefish, Sucker (Largescale Sucker and Bridgelip Sucker), Crayfish, Common Carp; other species that were less frequently collected and were grouped as "Other" (see Table F).

7. QAQC review of the dataset preparation/clean-up steps in R was conducted throughout the process by reviewing outputs with an emphasis on data to which changes were made (as described in this section) and spot-checking other results.

Table F: Species names and classifiers used for the biota tissue dataset.

Common Name	cies Code[1]	Taxon Name	Taxon Group
Bridgelip Sucker	BLS	*Catostomus columbianus*	Sucker
Brown Trout	BRT	*Salmo trutta*	Other
Common Carp	CCP	*Cyprinus carpio*	Common Carp
Crayfish [2]	CRF	Astacidae	Crayfish
:rayfish (Signal Crayfish)	CRF	*Pacifastacus leniusculus*	Crayfish
Kokanee	KOK	*Oncorhynchus nerka*	Other
Largemouth Bass	LMB	*Micropterus salmoides*	Other
Largescale Sucker	LSS	*:atostomus macrocheilus*	Sucker
Mountain Whitefish	MWF	*Prosopium williamsoni*	lountain Whitefish
Northern Pikeminnow[3]	NPM	*?tychocheilus oregonensis*	Other
Rainbow Trout	RBT	*Oncorhynchus mykiss*	Rainbow Trout
Smallmouth Bass	SMB	*Micropterus dolomieui*	Other
Walleye	WAL	*Sander vitreus* [4]	Other
White Crappie	WCP	*Pomoxis annularis*	Other
Yellow Perch	YP	*Perca flavescens*	Other

Table Notes:

[1] Species codes were selected from Spokane River studies and are used for this project.

[2] In some reports, Crayfish was only identified to the family level (Davis and Serdar 1994, Johnson 1994a).

[3] Previously referred to as Northern Squawfish.

[4] Previous scientific name was *Stizostedion vitreum*.

4. CALCULATIONS

4.1. Additional Parameters

Additional parameters (added as "Constituents") were calculated in R and added to the tissue dataset. These parameters include:

1. Lipid normalized tPCB concentrations (C_{tPCB-L}, ng/kg lipid) were calculated from the wet weight concentration in fish (C_{tPCB}, ng/kg wet weight) and percent lipid content (L, %), as follows:

Equation 2:

$$C_{tPCB-L} = \frac{C_{tPCB}}{L/100\%}$$

Table G: Example calculation for lipid normalization.

Study ID: DSER0010
Sample ID: 4324444

Parameter	Value	Units
Cf =	195,360	ng/kg wet weight
L =	7.7	%
CL =	2,537,143	ng/kg lipid

2. Toxic Equivalencies (TEQ, ng TEQ/kg wet weight) were calculated as the sum product of wet weight concentration of individual dioxin-like PCBs ($C_{PCB(-x)}$, ng/kg wet weight) multiplied by their corresponding toxic equivalency factors (TEF, unitless) according to:

Equation 3:

$$TEQ = (C_{PCB-77} \times TEF_{PCB-77}) + (C_{PCB-81} \times TEF_{PCB-81}) + \ldots (C_{PCB-189} \times TEF_{PCB-189})$$

Where the TEF values for dioxin-like PCBs were based on published values by the World Health Organization (WHO) for fish, birds and mammals in 1998 (Van den Berg, Birnbaum et al. 1998); values for mammals were updated in 2005 (Van den Berg, Birnbaum et al. 2006).

Table H: Toxic equivalency factors for dioxin-like PCB congeners.

Dioxin-like PCBs	nstituent	/lammal 1998	TEF Bird	TEF Fish	/lammal 2005
ıon-ortho substituted	'CB-077	0.0001	0.05	0.0001	0.0001
ıon-ortho substituted	'CB-081	0.0001	0.1	0.0005	0.0003
ono-ortho substituted	'CB-105	0.0001	0.0001	).000005	0.00003
ono-ortho substituted	'CB-114	0.0005	0.0001	).000005	0.00003
ono-ortho substituted	'CB-118	0.0001	0.00001	).000005	0.00003
ono-ortho substituted	'CB-123	0.0001	0.00001	).000005	0.00003
ıon-ortho substituted	'CB-126	0.1	0.1	0.005	0.1
ono-ortho substituted	'CB-156	0.0005	0.0001	).000005	0.00003
ono-ortho substituted	'CB-157	0.0005	0.0001	).000005	0.00003
ono-ortho substituted	'CB-167	0.00001	0.00001	).000005	0.00003
ıon-ortho substituted	'CB-169	0.01	0.001	0.00005	0.03
ono-ortho substituted	'CB-189	0.0001	0.00001	).000005	0.00003

Table I: Example calculation of TEQs.

Study ID: DSER0010
Sample ID: 4324444

Congener	Result	Units	dblLimit	txtQual	TEF Mammal 2005	TEQ Mammal 2005 (LimitZero)	TEQ Mammal 2005 (LimitHalf)
PCB-077	255	ng/kg wet weight			0.0001	0.0255	0.0255
PCB-081	262	ng/kg wet weight			0.0003	0.0786	0.0786
PCB-105	4320	ng/kg wet weight			0.00003	0.1296	0.1296
PCB-114	444	ng/kg wet weight			0.00003	0.0133	0.0133
PCB-118	10800	ng/kg wet weight			0.00003	0.3240	0.3240
PCB-123	329	ng/kg wet weight			0.00003	0.0099	0.0099
PCB-126	85.3	ng/kg wet weight			0.1	8.5300	8.5300
PCB-156/157	807	ng/kg wet weight			0.00003	0.0242	0.0242
PCB-167	454	ng/kg wet weight			0.00003	0.0136	0.0136
PCB-169	67	ng/kg wet weight	3.9	U	0.03	0	0.0585
PCB-189	102	ng/kg wet weight	102	UJ	0.00003	0	0.0015
					TEQ sum:	9.15	9.21
					units:	ng TEQ/kg ww	ng TEQ/kg ww

Lipid normalized TEQs were calculated by dividing the wet weight TEQs by the lipid content (see Equation 2). In addition, a count of TEQ analytes (i.e., number of dioxin-like PCBs used in TEQ summaries; usually 11 or 12, depending on co-eluters) and a count of TEQ non-detects (i.e., number of dioxin-like PCBs with "U" variants in the "txtQual" field) were also calculated mainly to show the number of non-detects in the TEQ calculations.

3. In version 4 of the fish data package, individual congener constituents were summarized for the risk assessment analysis. While the project database contained individual congener data, the original data needed the "zero", "half" and "full" detection limit treatments applied in cases where congener concentrations were less than detection limits. This approach followed the three detection limit treatments applied to determine summed tPCB concentrations (Section 2.1). Specifically, individual congener that were less than the detection limit (i.e., "txtQual" contained a "U" variant) were substituted by zero, one-half or the full detection limit (see example in Table J).

Table J: Example calculation assigning detection limit treatments to congeners.

Study ID: WSTMP12
Sample ID: 1301011-13

Congener	Limit	Result	Units	Result Basis	Qualifier
PCB-081 (original)	0.55	3.03	ng/Kg	wet weight	U
PCB-081 - LimitZero	0.55	0	ng/Kg	wet weight	U
PCB-081 - Limit/2	0.55	0.275	ng/Kg	wet weight	U
PCB-081 - Limit	0.55	0.55	ng/Kg	wet weight	U

Individual congener concentrations were also lipid normalized by dividing the wet weight congener concentration by the lipid content (see Equation 2).

In addition to the summary statistics for the individual congener wet weight and lipid normalized results, counts of individual congener analytes (always equal to one) and the number of congener non-detects (equal to zero or one) were calculated in summary tables mainly to show the number of non-detect congeners in the dataset. The summary table also provides the congener detection limit concentrations.

4. In all versions of the fish data package, individual Aroclor constituents were summarized for the risk assessment analysis. While the project database contained individual Aroclor data, the original data needed the "zero", "half" and "full" detection limit treatments applied in cases where Aroclor concentrations were less than detection limits. This approach followed the three detection limit treatments applied to determine summed tPCB concentrations (Section 2.1). Specifically, individual Aroclors that were less than the detection limit (i.e., "txtQual" contained a "U" variant) were substituted by zero or one-half or the full detection limit (see example in Table K).

Table K: Example calculation assigning detection limit treatments to Aroclors.

Study ID: WSTMP12
Sample ID: 1301011-13

Congener	Limit	Result	Units	Result Basis	Qualifier
PCB-aroclor 1248 (original)	5,000	10,000	ng/Kg	wet weight	UJ
PCB-aroclor 1248 - LimitZero	5,000	0	ng/Kg	wet weight	UJ
PCB-aroclor 1248 - Limit/2	5,000	2,500	ng/Kg	wet weight	UJ
PCB-aroclor 1248 - Limit	5,000	5,000	ng/Kg	wet weight	UJ

Individual Aroclor concentrations were also lipid normalized by dividing the wet weight Aroclor concentration by the lipid content (see Equation 2).

In addition to the summary statistics for the individual Aroclor wet weight and lipid normalized results, counts of individual Aroclor analytes (always equal to one) and the number of Aroclor non-detects (equal to zero or one) were calculated in summary tables mainly to show the number of non-detect Aroclors in the dataset. The summary table also provides the Aroclor detection limit concentrations.

5. In version 4 of the fish data package, tPCB "congener equivalents" were calculated based on regression relationships between tPCB measured by Aroclor analysis and tPCB measured by congener analysis, for Spokane River fish samples were both types of analysis were used. Three studies measured PCBs in fish using both analytical methods: BERA0011, RJAC002, and WSTMP12. Based on the log-log (logarithm base 10) regressions for all three limit types (see
6.), tPCB Aroclor concentrations (LOG_{10} $C_{tPCB\text{-}A}$, ng/kg wet weight) were converted to tPCB "congener equivalents" (LOG_{10} $C_{tPCB\text{-}C\ EQU}$, ng/kg wet weight), according to:

Equation 3:

$$LOG_{10}\, C_{tPCB-C\ EQU} = m \times LOG_{10}\, C_{tPCB-A} + b$$

Where *m* is equal to the slope of the regression line and *b* is the y-intercept. While tPCB concentrations in common carp were higher than those in other fish species, there was no apparent bias related to species (i.e., data points for different species fall above and below the regressions lines equally; Figure A).

Regression coefficients and statistics for the three limit types are shown in Table L and an example of the congener equivalent conversion is shown in Table M. The statistics shown in Table L indicate statistically significant relationships for all limit types (i.e., p values much less than 0.01), with much of

the variability in the data explained by the linear regression models for the log(10) versus log(10) transformed data (i.e., high R-squared values).

Figure A: tPCB concentration by congener versus tPCB by Aroclor (Logarithm base 10 transformed values for ng/kg wet weight), for all limit types.

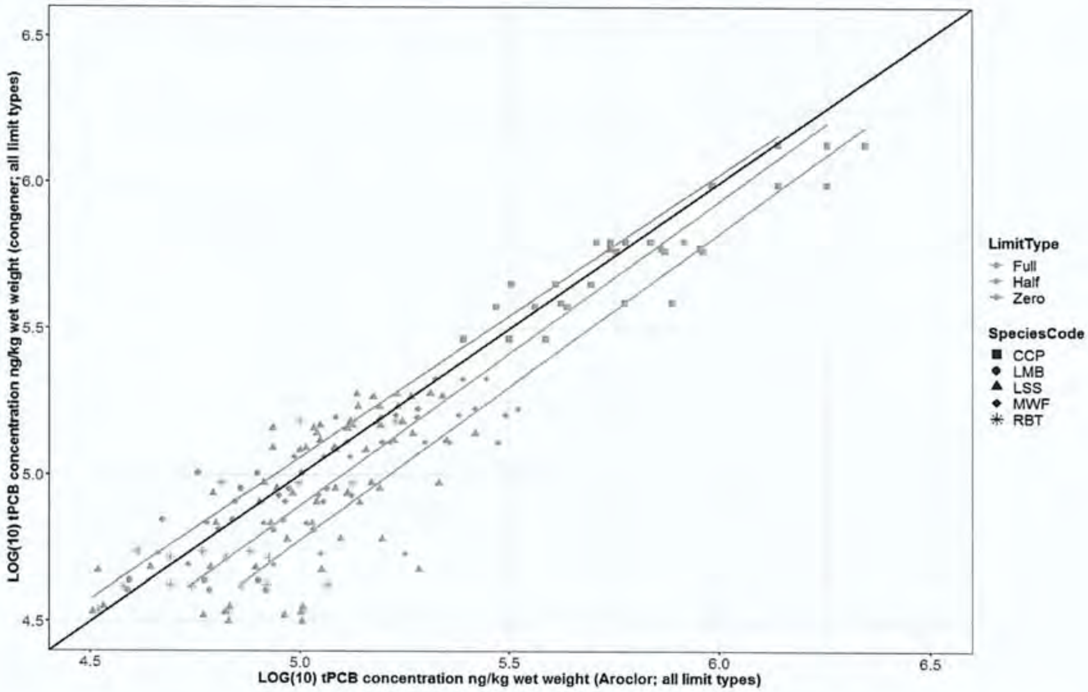

Table L: tPCB congener versus tPCB Aroclor (LOG(10) tPCB; ng/kg wet weight) regression coefficients and statistics

imitType	[slope)	lard error (m)	value (m)	y-intercept)	R-squared
Zero	ı.984	0.032	<0.01	0.130	0.94
Half	..088	0.048	<0.01	-0.569	0.90
Full	..100	0.063	<0.01	-0.756	0.84

Table M: Example calculation conversion of tPCB Aroclor to tPCB congener equivalent.

Study ID:)016
Sample ID: !33

ituent	Result	Units	ɘsult Basis

۱rochlors - LimitZero	ł1,000	ng/Kg	et weight
۱rochlors - Limit/2	ℑ1,600	ng/Kg	et weight
۱rochlors - Limit	22,200	ng/Kg	et weight
Ꞓ-EQU - LimitZero	ł6,869	ng/Kg	et weight
Ꞓ-EQU - Limit/2	;9,688	ng/Kg	et weight
Ꞓ-EQU - Limit	;9,374	ng/Kg	et weight

7. tPCB ratios were calculated for some of the exploratory plots provided in versions 2 and 3 of the fish data package. Specifically, ratios were calculated for:

- Analysis method: $tPCB - Aroclor / tPCB - congener$ (for fish samples analyzed by both methods)
- Limit type "full": $tPCB - Limit / tPCB - LimitZero$
- Limit type "half": $tPCB - Limit/2 / tPCB - LimitZero$

4.2. Statistical Summaries

Several summary statistics are provided in tables. The risk assessment tables summarize PCB concentrations in biota by year/scenario; species common name; tissue type; river stretch; and limit type. The individual congener and individual Aroclor tables are also grouped by constituent. Parameters in version 4 summary tables include:

- tPCB concentrations based on congener methods and congener equivalent conversions (wet weight and lipid-normalized),
- Lipid contents,
- TEQs (wet weight and lipid-normalized),
- Individual PCB congener concentrations for dioxin-like and NHL congeners (wet weight and lipid-normalized),
- Individual PCB Aroclor concentrations (wet weight and lipid-normalized),
- Count of PCB analytes (number of congeners or Aroclors in tPCB measurement) with count of non-detects and ratio of non-detects,
- Detection limits for individual congener and Aroclor PCBs

Statistics calculated include:

- Sample size,
- Arithmetic means,

- Minimums and maximums,
- 5th and 95th percentiles.

4.3. QAQC Review

A QAQC review of the calculations for all new parameters was conducted by reviewing equations used in the code and spot-checking the calculated values (i.e., for several samples, newly-calculated parameter values in the R output file were cross-checked with values calculated separately in Excel). The same approach was used for reviewing calculations of mean values and other statistics for all parameters reported in the summary tables (i.e., for various groups of samples, mean values were calculated in Excel to cross-check values calculated in R and reported in summary tables).

5. DATA SUMMARY PACKAGES

Fish tissue data packages (multiple versions, each with updated summaries or new information) containing figures, tables, and maps have been provided to the Client separately. The contents of these packages are documented in a file tracker provided with the data package.

6. REFERENCES

Davis, D., A. Johnson and D. Serdar (1995). Washington State Pesticide Monitoring Program: 1993 Fish Tissue Sampling Report. Olympia, WA, Washington State Department of Ecology.

Davis, D. and D. Serdar (1994). Results of 1993 screening survey on PCBs and Metals in the Spokane River (with corrections). Washington State Department of Ecology. Olympia, WA.

Ecology, (Washington State Department of Ecology) (1995). Department of Ecology 1993-94 Investigation of PCBs in the Spokane River. Washington State Department of Ecology. Olympia, WA.

Ecology, (Washington State Department of Ecology) (2018). EIM Help – Entering Non-Detects and Estimates. **Version 2.7:** 3.

Era-Miller, B. (2015). Lake Spokane: PCBs in Carp. Washington State Department of Ecology. Olympia, WA.

Era-Miller, B. (2015). Quality Assurance Project Plan: Spokane River PCBs and Other Toxics Long Term Monitoring at the Spokane Tribal Boundary. Washington State Department of Ecology. Olympia, WA.

Jack, R. and M. Roose (2002). Analysis of Fish Tissue from Long Lake (Spokane River) for PCBs and Selected Metals. Washington State Department of Ecology. Olympia, WA.

Johnson, A. (1994a). PCB and Lead Results for 1994 Spokane River Fish Samples. Toxics Investigation Section - Washington State Department of Ecology. WA.

Johnson, A. (1994b). Planar PCBs in Spokane River Fish. Toxics, Compliance, and Ground Water Investigations Section - Washington State Department of Ecology. WA.

Johnson, A. (1997). 1996 Results on PCBs in Upper Spokane River Fish. Washington State Department of Ecology. WA.

Johnson, A. (2000). Results from Analyzing PCBs in 1999 Spokane River Fish and Crayfish Samples. Washington State Department of Ecology. WA.

Joy, J. (1984). Letter on data concerning PCBs in fish taken from the Spokane River by the U.S. Environmental Protection Agency and the Washington State Department of Ecology. Jeff Sher, Spokane Spokesman Review. Olympia, WA, Washington State Department of Ecology**:** 7.

Seiders, K., C. Deligeannis, P. Sandvik and M. McCall (2014). Freshwater Fish Contaminant Monitoring Program: 2012 Results. Washington State Department of Ecology. Olympia, WA**:** 29.

Serdar, D. and A. Johnson (2006). PCBs, PBDEs, and Selected Metals in Spokane River Fish, 2005. Washington State Department of Ecology. Olympia, WA.

Serdar, D., A. Johnson and D. Davis (1994). Survey of Chemical Contaminants in Ten Washington Lakes. Environmental Investigations and Laboratory Services Program. Olympia, WA, Washington State Department of Ecology.

Serdar, D., B. Lubliner, A. Johnson and D. Norton (2011). Spokane River PCB Source Assessment 2003-2007. Washington State Department of Ecology. Olympia, WA.

Van den Berg, M., L. S. Birnbaum, A. T. C. Bosveld, B. Brunstrlim, P. Cook, M. Feeley, J. A. H. P. Giesy, R. Hasegawa, S. W. Kennedy, T. Kubiak, J. C. Larsen and e. al. (1998). "Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife." Environmental Health Perspectives **106**(12): 775-792.

Van den Berg, M., L. S. Birnbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker and R. E. Peterson (2006). "The 2005 World Health Organization reevaluation of human and Mammalian toxic equivalency factors for dioxins and dioxin-like compounds." Toxicol Sci **93**(2): 223-241.

Wong, S. (2018). Evaluation of Fish Hatcheries as Sources of PCBs to the Spokane River. Washington State Department of Ecology. Olympia, WA.

Wong, S. and B. Era-Miller (2019a). Final Validated Data - Spokane Biofilm Project.

Wong, S. and B. Era-Miller (2019b). Using Biofilms to Identify Sources of PCBs to the Spokane River. Spokane River Forum Conference 2019. Washington State Department of Ecology. Spokane, WA.

Wong, S. and B. Era-Miller (2019c). Quality Assurance Project Plan: Measuring PCBs in Biofilm, Sediment and Invertebrates in the Spokane River: Screening Study. Washington State Department of Ecology. Olympia, WA.

DANIEL SCHLENK
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Environmental Toxicology
Department of Environmental Sciences
University of California, Riverside
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EDUCATION

Ph.D. Biochemical Toxicology	Oregon State University	June 1989
B.S. Toxicology;	Northeast Louisiana University (University of Louisiana Monroe)	May 1984

Postdoctoral Fellow: Duke University 1989-1991

EMPLOYMENT

2000-present; Professor, Environmental Toxicology, Department of Environmental Sciences, University of California, Riverside

1999-2000 Program Coordinator of Environmental Toxicology Program, Environmental and Community Health Research Program, School of Pharmacy, University of Mississippi

1998-2000 Associate Professor of Pharmacology and Toxicology, University of Mississippi (University, MS).

1998-2000 Coordinator for the Graduate Program in Pharmacology, University of Mississippi (University, MS)

1995-1998 Assistant Professor of Pharmacology and Toxicology University of Mississippi (University, MS).

1991-1995 Assistant Professor Toxicology, University of Arkansas for Medical Sciences (Little Rock, AR).

1989-1991 Postdoctoral Fellow, Duke University Marine Laboratory, Integrated Toxicology Program,(Beaufort, N.C.).

1986-1989 Predoctoral Fellow, Oregon State University, Toxicology Program (Corvallis, OR).

1985-1986 Research Assistant, Oregon State University, College of Pharmacy (Corvallis, OR).

1984-1985 Research Assistant, Oregon State University, Department of Environmental Engineering (Corvallis, OR).

ACADEMIC HONORS

NIEHS Postdoctoral Fellow, Duke University 1989-1991
NIEHS Predoctoral Fellow, Oregon State University 1986-1989

Visiting Scholar Department of Biochemistry; Chinese University of Hong Kong 1995; 1998; 1999
Ray Lankester Investigatorship -Marine Biological Association of the United Kingdom 1998
Visiting Scholar of the Instituto Del Mare, Venice Italy 1999

University of Mississippi; School of Pharmacy, Faculty Research Award, 1999-2000.

George E. Brown, Jr. Award (UC-MEXUS) Co-PI with J. Garcia-Hernandez 2001

Visiting Scholar CSIRO Laboratory Lucas Heights, Australia 2003

Fellow American Association for the Advancement of Science 2010

Distinguished Fellow of the State Key Laboratory for Marine Environmental Science in Xiamen University of China 2011

Visiting Professor Fellowship of the National Counsel of Technological and Scientific Development at the University of Sao Jose Rio Preto, Brazil 2014-2015.

Outstanding Foreign Scientist Invitation Program; College of Science Sungkyunkwan University, Korea 2016

Fellow Society of Environmental Toxicology and Chemistry 2017

SOCIETY MEMBERSHIPS AND OFFICES

Member of Society of Environmental Toxicology and Chemistry, 1992-present
Founding Board Member and Secretary/Treasurer Mid-South SETAC 1995-1996; Vice President 1996-1997; President 1998-1999
Member of Society of Toxicology, 1987-present
Member of the International Society for the Study of Xenobiotics 1999-2009
Member Society of Environmental Toxicology and Chemistry Education Committee 1998- 2001.
Member Society of Environmental Toxicology and Chemistry Organizing Committee for Nashville 2000; Platform Session Co-chair
Secretary and Member of South Central Chapter of Society of Toxicology 1999-2000.
Board member of Southern California Regional Chapter of the Society of Toxicology 2002-2004.

Vice President of Southern California Regional Chapter of the Society of Environmental Toxicology and Chemistry 2004
President of Southern California Regional Chapter of the Society of Environmental Toxicology and Chemistry 2005
Member of the Board of Directors for the North American Society of Environmental Toxicology and Chemistry 2003-2006
Member of the Board of Trustees for the SETAC North America Board of Endowment Fund 2006-2014
Co-Organizer 16th International Symposium for Pollution Responses in Marine Organisms. Long Beach, CA May 15-18, 2011.
Co-Chair for the North American Society of Environmental Toxicology and Chemistry Annual meeting. Long Beach, CA Nov 11-15, 2012.

EDITORIAL RESPONSIBILITIES

Associate Editor *Environmental Science and Technology* (2016-present)

Associate Editor *Environmental Science and Technology Letters* (2016-present)

Co-Editor in Chief- *Aquatic Toxicology* (2005-2011)

Editorial Board: *Toxicological Sciences* (2000-present), *Marine Environmental Research* (2000-present), *Aquatic Toxicology* (2001-present), *Environmental Toxicology and Chemistry* (2003-2005).

Ad Hoc reviewer for:

Proceedings of the National Academy of Scinecs, Science, PLOSone; Scientific Reports; Molecular Pharmacology; Ecological adaptations; Biomarker; Neurotoxicology and Teratogenicity; Archives of Environmental Contamination and Toxicology; Comparative Biochemistry and Physiology; Drug Metabolism and Disposition; Biochemical Pharmacology; Journal of Aquatic Animal Health; Toxicology and Applied Pharmacology, Environmental and Molecular Mutagenesis, Gene, Journal of Toxicology and Environmental Health, Biochemistry and Biophysics Acta; International Journal of Environmental Analytical Chemistry; Physiological Zoology; Human and Ecological Risk Assessment; Science of the Total Environment; Naturwissenschaften; Environmental Pollution; Chemico-biological Interactions; Marine Pollution Bulletin; Journal of Molecular Evolution; Chemical Research in Toxicology; Integrated Environmental Assessment and Management; Pesticide Biochemistry and Physiology; Ecotoxicology and Environmental Safety; Bulletin of Environmental Contamination and Toxicology; Environmental Impact Assessments; Hydrobiologia; Expert Opinions in Drug Metabolism and Toxicology; Chemosphere; Zebrafish; Toxicology Letters; Journal of Toxicology

INTERNATIONAL REVIEW PANELS

International Review Panel for the School of Life Sciences, Chinese University of Hong Kong (2014); International Steering Committee for University of Waterloo "Determining the efficacy of emerging contaminant removal within existing treatment trains relevant to Canadian conditions through chemical and toxicological assessments.".(2010-2013). Canadian Water Network Grant Review (2007; 2009) National Environmental Research Council , United Kingdom (2008); National Science Foundation, South Africa (2009); The Faculty of Science at University of Gothenburg (2009); Danish Council of Strategic Research (2012); Expert Consultation EEWAG, Switzerland (2013). The Research Council of Norway (2013); Faculty of Science, Chinese University of Hong Kong (2014); Advisory Board; Ecological effects of Brine Discharge, National Centre of Excellence in Desalination Australia (2014-2016). Grant Review European Commission (2015). Research Grants Council Hong Kong (2015). Research Oversight Committee, Ecotoxchip Program, Genome Quebec, Canada (2017-2019).

FEDERAL REVIEW PANELS

Chair USEPA FIFRA Science Advisory Panel (2012-2014)
Permanent Member USEPA FIFRA Science Advisory Panel (2007-2012)
Member USEPA Chemical Safety Advisory Committee (2016)
Member USEPA Science Advisory Committee on Chemicals (2017-
Ad hoc reviewer NIEHS Freshwater Biomedical Centers (1996); US Department of Agriculture (1997-2000) and National Science Foundation (1996-present). NOAA Oceans and Human Health Initiative Grant Review Panel (2005); USEPA Endocrine Disrupter Mixtures Grant Review Panel (2005); USEPA Science Advisory Board Aquatic Life Criteria Guidelines (2005); NIEHS P30 Core-Center Applications (2008); NIEHS Superfund Research Program P42 Center Applicatons (2016)

STATE OR FOUNDATION REVIEW PANELS

Ad Hoc reviewer for California SEAGRANT (1999-present); Woods Hole SEAGRANT (1994-present); Delaware SEAGRANT (1992); Hudson River Foundation (2000); TMDL review for Diazinon in Chollas Creek, CA (2001); University of California Marine Council (2001-2006); California Surface Waters Ambient Monitoring Program Scientific Planning and Review Committee (2002); California Aquatic Pesticide Monitoring Scientific Advisory Panel (2002-2004); UC Water Resources Research Institute (2003-2005); Environmental Effects Working Group, San Francisco Estuary Institute (2005-present). Technical Advisory Committee, Santa Ana Regional Water Quality Control Board (2006). Pelagic Organism Decline Advisory Committee (2007-2010). National Water Research Institute Scientific Advisory Panel (2008). Blue-Ribbon Panel for Contaminants of Emerging Concern in Recycled Water for the State of California (2009-2010). Science Advisory Panel for impacts of desalination brine discharge for the State of California (2009); Blue Ribbon Panel for the Ecological Effects of Contaminants of Emerging Concern (2010-2011). Advisory Panel for Effects of CeCs in surface waters (2014). External Reviewer for California State University of Long Beach Program Review for Biological Sciences (2015). Grant review California Department of Fish and

Wildlife (2015). Science Advisory Panel for CeCs in Recycled Water; CA regional water control board (2017-2018)

INVITED PRESENTATIONS (235) (**International engagements in 20 countries-104)**

1989 **Third Institute of Oceanography, Xiamen University, Xiamen, China**.
1989 **Plymouth Marine Laboratory, Plymouth, United Kingdom**.
1991 Department of Biology, University of Arkansas Little Rock, Little Rock, AR.
1991 U.S. Fish and Wildlife Fish Farming Experimental Laboratory, Stuttgart, AR.
1992 Department of Biochemistry, University of Arkansas for Medical Sciences, Little Rock, AR.
1992 Department of Pharmacology and Toxicology, Northeast Louisiana University, Monroe, LA.
1992 US FDA National Center for Toxicological Research, Jefferson, AR.
1992 Toxicology Program, Oregon State University, Covallis, OR.
1993 Southern Regional Research Center, US Department of Agriculture, New Orleans, LA.
1993 Department of Pharmacology and Toxicology, Medical College of Wisconsin, Milwaukee, WS.
1993 Department of Biochemistry, Louisiana State University, Baton Rouge, LA.
1994 Department of Biology University of Central Arkansas, Conway, AR.
1994 **International Association for Great Lakes research, Basic and Applied Aspects of Aquatic Biotechnology Symposium, Windsor, Ontario**.
1994 Society of Environmental Toxicology and Chemistry, Biotransformation: Influence on Bioaccumulation and Toxicity. Denver CO.
1995 Southern States Mercury Task Force, Jackson, MS.
1995 Department of Pharmacognosy, University of Mississippi, Oxford, MS.
1995 College of Veterinary Medicine, Mississippi State University, Starkville, MS.
1995 Southeastern Regional Chapter of Society of Toxicology, University of Georgia, Athens, GA.
1995 **Department of Biochemistry, The Chinese University of Hong Kong**.
1996 Department of Biology, University of Mississippi, Oxford, MS.
1996 Arkansas Chapter of the American Fisheries Society, Arkansas State University, Jonesboro, AR.
1996 Department of Biology, University of Memphis, Memphis, TN.
1997 Northeast Louisiana University, Division of Toxicology, Monroe, LA.
1997 **European Society for Comparative Physiology and Biochemistry: Third International Symposium on: Research for Aquaculture: Fundamental and Applied Aspects, Barcelona, Spain.**
1998 Department of Environmental and Molecular Toxicology, Oregon State University, Corvallis OR
1998 **2nd International Conference on Marine Pollution and Ecotoxicology Hong Kong, China**
1998 **Marine Biological Association of the United Kingdom Plymouth UK**
1998 **Department of Biochemistry, The Chinese University of Hong Kong**
1998 Department of Pharmacology, University of Mississippi
1999 Trimethylaminuria Workshop; National Institutes of Health, Bethesda MD.

1999 Instructor for Aquatic Toxicology Workshop; 10th International Pollution Responses in Marine Organisms Symposium, College of William and Mary, Williamsburg, VA
1999 Center for Bioenvironmental Research, Tulane University, New Orleans, LA
1999 **Beijing School of Pharmacy, Beijing Medical University, Beijing China**
1999 **Department of Biochemistry, The Chinese University of Hong Kong**
1999 Department of Biology Ouachita Baptist University, Arkadelphia, AR
1999 Department of Biology, Rhodes College, Memphis, TN
1999 **Instituto Del Mare, Venice Italy**
1999 Nicolas School of the Environment, Duke University, Durham, North Carolina
1999 Nicolas School of the Environment , Duke University Marine Laboratory, Beaufort, North Carolina
2000 Oregon Department of Environmental Quality Task Force on the Use of Biomarkers in determine sediment quality criteria in Portland Harbor and the lower Williamette River System, OR; Portland, OR.
2000 Department of Pharmacognosy, University of Mississippi, University, MS.
2000 Environmental Toxicology Program University of California, Davis
2000 Environmental Chemistry/Toxicology Seminar, University of California, Riverside, CA
2000 USDA National Salinity Laboratory, Riverside, CA
2001 Southern California SETAC, Irvine, CA
2001 Southern California Coastal Water Research Project, Westminister, CA
2001 Moldova State University, Moldova
2001 Environmental Monitoring and Assessment Program Symposium, USEPA Pennsacola Beach, FL
2001 Hudson River Foundation, New York, NY
2001 City of Hope Cancer Research Center, Duarte, CA.
2002 2nd International Trimethylaminuria Workshop, National Institutes of Health, Bethesda, MD
2002 Water Education Foundation; Association of Groudwater Agencies; Managing Groundwater Basins for Water Quality and Supply, Ontario, CA
2002 European Society of Environmental Toxicology and Chemistry, Vienna Austria
2002 Institute of Zoology, Moldova Academy of Sciences, Moldova
2002 Southern California SETAC annual meeting: Symposium: Pharmaceuticals in the Environment UC-Riverside
2002 Sixth International Symposium on Cytochrome P450 Biodiversity, Los Angeles (UCLA), CA
2002 UC-Toxics Marine Toxicology Symposium, Bodega Marine Laboratory, CA
2002 Department of Environmental Engineering Seminar Series, UC-Berkeley, CA
2002 Integrated Toxicology Program, Duke University Durham, NC
2002 Department of Biological Sciences, Redlands University, Redlands, CA
2002 Toxicology Program; University of California, Irvine, Irvine, CA
2003 CWEA Specialty Topics Conference on Emerging Pollutants Endocrine Disrupting Chemicals/Pharmaceuticals, El Camino Country Club, Oceanside, CA
2003 Southern California Association of POTWs. Emerging Pollutants, OCSD, Fountain Valley, CA

2003 California Association of Sanitation Agencies; Emerging Pollutants, Yosemite, CA.

2003 Australian Society of Ecotoxicology Regional Chapter Meeting, Sydney, Australia

2003 Department of Chemistry Woolongong University, Woolongong, Australia

2003 CSIRO Center of Analytical Chemistry Adelaide, Australia

2004 University of California Water Resources Research Institute Board of Directors Meeting, Ontario, CA.

2004 International Society of the Study of Xenobiotics Symposia on Environmental Xenobiotic Metabolism Vancouver, British Columbia, Canada

2004 Coastal Marine Toxicology Symposium, UC-Davis, Bodega Marine Laboratory, Bodega Bay, CA.

2004 VIII Brazilian Ecotoxicology Meeting, Florianopolis, Brazil

2004 Department of Zoophysiology University of Gothenburg, Gothenburg, Sweden

2005 Orange County Sanitation District "Fate of Pharmaceuticals in the Environment" Fountain Valley, CA

2005 Schools of Pharmacy and Environmental Health, University of Washington, Seattle, WA

2005 3rd International Conference of Ecological Chemistry, Chisinau, Moldova

2005 Texas Institute of Environmental and Human Health, Texas Tech University, Lubbock, TX

2005 Canadian Rivers Institute, University of New Brunswick, St. John, Canada

2005 Department of Biology California State University at Long Beach, Long Beach, CA

2005 Integrated Graduate Program, University of Turku, Turku Finland.

2005 Industrial Environmental Association/California Manufacturers & Technology Association Conference (Dec 15) San Diego, CA

2006 California Water Environment Association's Emerging Contaminants: Endocrine Disrupting Compounds (EDCs) and Pharmaceutical and Personal Care Products (PPCPs) in Wastewater One –Day Specialty Conference January 12, at Los Angeles County Sanitation Districts, Whittier, CA

2006 California Water Environment Association's Emerging Contaminants: Endocrine Disrupting Compounds (EDCs) and Pharmaceutical and Personal Care Products (PPCPs) in Wastewater One –Day Specialty Conference January 18, at Central Contra Costa Sanitary District, Martinez, CA

2006 American Chemical Society Western Region, Jan 24, Orange, CA

2006 Aquatic Toxicology Course, California State University at Long Beach March 14, Long Beach, CA

2006 Department of Chemistry, University of California, Riverside, CA May 5.

2006 Santa Ana Regional Water Quality Control Board, Riverside, CA July 20.

2006 World Oceans Conference, Long Beach, CA September 19.

2006 Physicians for Social Responsibility, Metropolitan Water District, Los Angeles, CA September 28.

2006 Aquatic Toxicity Workshop on Selenium, Jaspar, Alberta October 1-5.

2006 Department of Zoology, University of Miami, Ohio. October 12.

2006 Department of Molecular and Environmental Biology, Hanyang University Seoul, South Korea October 17.

2006 Department of Biology Korean University, Seoul, South Korea. October 18.

2006 Environmental Toxicology Program, University of Mississippi, Oxford, MS October 27.

2006 Orange County Water District Science Advisory Board, Anaheim, CA November 14.

2007 Workshop on Trace Organics: Mapping a Collaborative Research Roadmap. WERF, Hyatt Regency Hotel, San Francisco, CA May 17-18.

2007 Pharmaceuticals and Personal Care Products in the Environment Symposium, California EPA Department of Toxic Substances Control, Sacramento, CA May 22.

2007 5th International Conference on Marine Pollution and Ecotoxicology, City University of Hong Kong June 3-6.

2007 Guangzhou Institute of Geochemistry Chinese Academy of Sciences Guangzhou, China June 7.

2007 Recursos del Mar, Cinvestav, Unidat Merida, Mexico July 24.

2007 CSU-Environmental Physiology and Toxicology Workshop, Catalina Island Nov 9-21

2008 Symposium of Molecular Chirality 2008, Okayama University, Japan May 22-23

2008 Puschino State University, Moscow, Russia May 27

2008 Southern Nevada Water Authority, Las Vegas, NV August 19.

2008 National Center for Ecological Analysis and Synthesis, Santa Barbara, CA Sept 4.

2008 Plenary Speaker, Calfed Bay Delta Annual Symposium, Sacramento, CA Oct 22.

2009 Invited Speaker: State of the Science. Managing Contaminants of Emerging Concern in California: A Workshop to Develop Processes for Prioritizing, Monitoring, and Determining Thresholds of Concern April 28-29, 2009 Costs Mesa, CA

2009 Invited Speaker Micropol & Ecohazard 2009; 6th International Water Association/Groundwater Resources Association of California Specialized Conference on Assessment and Control of Micropollutants/Hazardsous Substances in Water, San Francisco, CA June 10.

2010 Invited Speaker Santa Ana Watershed Project Authority; Jan 21, 2010. Riverside, CA

2010 Invited Speaker College of Veterinary Medicine, Oklahoma State University, Stillwater, OK Jan 26, 2010.

2010 Invited Speaker American Chemical Society, Emerging Contaminants in California's Coastal and Estuarine Ecosystems San Francisco, CA Mar 25, 2010

2010 Invited Speaker Department of Zoology, Southern Illinois University, Carbondale, IL Apr 22, 2010.

2010 Invited Speaker: Department of Pesticide Regulation, Sacramento CA May 10, 2010

2010 Invited Speaker: California Green Chemistry Workshop; Indicators of Ecotoxicity Hazards and Exposure Potential, Office of Environmental and Human Health Assessment, Berkeley, CA May 11, 2010

2010 Invited Speaker: Northern California Society of Environmental Toxicology and Chemistry, Berkeley, CA May 13, 2010

2010 Invited Speaker Interagency Ecological Program Symposium, Sacramento State University, Sacramento, CA May 25, 2010.

2010 Webinar California Water Quality Monitoring Collaboration Network, May 27,

2010

2010 6th International Conference on Marine Pollution and Ecotoxicology, City University of Hong Kong May 31-June 3.

2010 International Workshop on Emerging Contaminants, Xiamen University Dec 14-15.

2010 Department of Biochemistry, Chinese University of Hong Kong Dec 16.

2011 Environmental and Occupational Health Department Technical Symposium on Pharmaceuticals and Personal Care Products in Water Supplies: Potential Impacts and Sustainable Solutions, California State University of Northridge Feb 16.

2011 Society of Toxicology Special Symposium: Emerging Issues at the Intersection of Reproductive and Mixtures Toxicology, Washington DC. Mar 7-10.

2011 Department of Environmental Sciences, Baylor University Mar 17

2011 Department of Biology University of Alberta, Edmonton, Canada Apr 6.

2011 College of Environmental and Resource Science, Zhejiang University, Hanzhou, China August 15

2011 Institute of Urban Environment, Chinese Academy of Sciences, Xiamen China August 17

2011 College of Oceanography and Environmental Science, Xiamen University, Xiamen China August 19

2011 Keynote Speaker: Fragranced Personal Care Products and Environmental Change: Scientific, Social, and Policy Perspectives. UC Davis, IGERT Workshop Sept 16

2011 Keynote Speaker: State of California Regional Monitoring Program Annual Meeting. Oakland Mariott, October 4.

2011 WEFTEC Workshop Designer Water: CECs and The California State Water Resources Control Board CEC Panel Findings and Implications. Los Angeles Conventions Center, October 15.

2011 Chinese 1st International Workshop on Environment and Health. Institute of Urban Environment Chinese Academy of Sciences. Xiamen, China Dec 14.

2011 Workshop on Environmental Toxicology and Publishing Xiamen University Dec 14-20.

2012 Mote Marine Laboratory, Sarasota Florida Jan 9.

2012 School of Life and Environmental Sciences, Deakin University, Warrnambool, Australia Mar 30.

2012 Environmental Toxicology Program, Clemson University, SC Apr 5.

2012 Invited Speaker; Presidential Inauguration of Paul Ferguson, University of Maine, Orono, Maine Apr 19.

2012 Department of Biochemistry and Marine Sciences, University of Maine, Orono, Maine. Apr 20.

2012 Invited Speaker; Experimental Biology Meetings; Comparative and Evolutionary Physiology Section; San Diego, CA Apr 23.

2012 Earth 101: Where's your Water From? UCR Extension, May 10

2012 Oekotoxzentrum Centre Ecotox, EAWAG/EPFL, Zurich, Switzerland; May 25.

2012 Arlington Rotary Club, Riverside, CA August 21.

2012 Invited Speaker, Commemorating the 50th Anniversary of Silent Spring; Society of Environmental Toxicology and Chemistry Nov 12.

2012 Invited Speaker, Prioritizing Contaminants of Emerging Concern (CECs) for Monitoring in California. Society of Environmental Toxicology and Chemistry Nov

13.

2012 Unidad de Química Sisal, UNAM. Yucatan, Mexico November 28

2013 Environmental Toxicology Graduate Program, University of California, Riverside, CA January 8.

2013 Webinar California Water Quality Monitoring Collaboration Network, Feb 14.

2013 Marine Science Institute, University of Texas, Port Aransas, TX, Mar 28

2013 University of Western Australia Oceans Institute, Perth Australia July 4.

2013 USGS Columbia, Mo. Aug 23.

2013 State of California Pilot Study on Monitoring of Constituents of Emerging Concern in Aquatic Ecosystems, SCCWRP Costa Mesa, CA Sept 12

2013 National Academy of Sciences, EPA Laboratory Efficiency, Washington DC Sept 17

2013 International Workshop on Risk Management and Control of Chemicals, Dalian, China Oct 14

2013 Norwegian Institute for Water Research, Oslo, Norway Oct 22

2013 4th Fresenius Conference, Dusseldorf, Germany Oct 25

2014 National Academy of Sciences, Risk and Ecological Effects of Greywater Jan 21

2014 Southern California Coastal Water Research Project Jan 23

2014 3rd International Salinity Forum, Riverside, CA June 17

2014 XIII Brazilian Ecotoxicology Congress; Guarapari Brazil. Sept 24

2014 Química e Ciências Ambientais; IBILCE – UNESP; São José do Rio Preto, Brazil Sept 29

2014 Departamento de Bioquimica, CCB; Lab.Biomarcadores de Contaminacao Aquatica e Imunoquimica; Nucleo de Estudos em Patologia Aquicola, CCA; Universidade Federal De Santa Catarina; Florianopolis Oct 6

2014 Universidade Federal De Santa Catarina; Programa de Pos-graduaco em aquicultura; Florianopolis, Brazil Oct 7

2015 Superfund Research Program Webinar, Understanding Aging in Contaminant Bioavailability and Remediation, NIEHS Feb 9

2015 Department of Environmental and Molecular Toxicology, Oregon State University, Corvallis, Feb 12

2015 Department of Biology University of Alberta, Edmonton, Canada Apr 3.

2015 Murdoch University, Perth, Western Australia Apr 17.

2015 CSIRO, Adelaide, Southern Australia Apr 24.

2015 CSIRO, Lucas Heights, Sydney, New South Wales, Australia Apr 27.

2015 Integrated Toxicology Program, Duke University May 6.

2015 Center for Environmental and Human Toxicology, University of Florida Aug 24.

2015 Química e Ciências Ambientais; IBILCE – UNESP; São José do Rio Preto, Brazil Sept 17

2015 Laboratório de Toxicologia Ambiental Escola Nacional de Saúde Pública – ENSP Fundação Oswaldo Cruz – FIOCRUZ, Rio De Janeiro, Brazil Sept 11

2015 International Symposium on Persistent and Toxic Substances, Riverside, CA Nov 16.

2016 Society of Toxicology, New Orleans, LA Mar 13.

2016 Biological Sciences Club, Hendrix University, Conway AR, Mar 17.

2016 Department of Pharmacology and Toxicology, University of Arkansas for Medical Sciences, Little Rock, AR Mar 18.

2016 Interagency Ecological Program; California Department of Water Resources, Folsum, CA Apr 20.

2016 School of Life and Environmental Sciences, Deakin University-Warrnabool, Victoria, Australia Apr 27

2016 College of Science; Sungkyunkwan University, Korea July 7

2016 Panelist for Singapore International Water Week "Hot Topics: Bioanalytical Tools for Water Quality July 11.

2016 National Academy of Sciences, Implementation of Adverse Outcome Pathways in the Ecological Risk Assessment of RNAi products. July 29

2016 International Symposium for Toxic and Persistent Substances; Leipzig Germany. October 12.

2016 Department of Biological Sciences, University of North Texas, Denton TX. October 14.

2016 Southern California Society of Environmental Toxicology and Chemistry, Fullerton, CA. October 26.

2016 National Water Research Institute, Clarke Award Ceremony, Newport, CA Nov 4

2016 North American Society of Environmental Toxicology and Chemistry, Orlando Florida Nov 8.

2016 Integrated Toxicology and Environmental Health Program, Duke University, Durham, NC Dec 2

2016 Superfund Research Program, 50 year Anniversary of NIEHS, NIH-FEST, Research Triangle Park, NC Dec 6.

2017 Workshop on Contaminants in the San Francisco Bay-Delta: Approaches to Evaluate Effects of Multiple Stressors; Using Adverse Outcome Pathways to characterize mixture interactions of San Francisco Bay Delta contaminants on fish feminization and the potential impact of climate change as a non-chemical stressor. UC-Davis, CA Jan 31.

2017 American Chemical Society, San Francisco, CA Apr 5.

2017 Toxicology Program, Iowa State University, Ames IA Apr 18.

2017 Wuhan China Academy of Science (Hydrobiology) June 21.

2017 Qingdao China Academy of Science (Fisheries) June 23.

2017 Ocean University of China, Qingdao, China June 23.

2017 Yantai China Academy of Science (Coastal zone policy), June 25.

2017 Shenyang China Academy of Science (Applied Ecology), June 27.

2017 Shenyang University Department of Soil Science, June 27.

2017 Fish Toxicology In Silico Workshop, Kristianeberg, Sweden Aug 17.

2017 International Society for the Study of Persistent and Toxic Substances (Keynote speaker); Nagoya, Japan September 26.

2017 Environmental Toxicology Seminar, Clemson University (Webinar) September 20

2017 Wavelength Brewery; Vista, CA Oct 6.

2017 Peking University Beijing, China Oct 16.

2017 Center for Eco-Environmental Sciences, Chinese Academy of Science. Beijing, China Oct 17.

2017 Center for Ecotoxicology Chinese Academy of Sciences, Beijing, China Oct 17

2017 Zhejiang University of Science and Technology, Hangzhou, China Oct 19

2017 National Conference for Environmental Chemistry Hangzhou, China Oct 20 and Oct 21.

2017 Fish Physiology and Aquaculture Meetings Xiamen University, China Oct 23.

2017 Center of Environmental Science Jinan University, Guangzhou, China Oct 24.
2017 Department of Environmental Sciences, Chinese University of Hong Kong Oct 25.
2017 Department of Environmental and Chemical Engineering, Hong Kong Polytechnic University Oct 26.
2017 Environmental Sciences Seminar, Hong Kong University Oct 27.
2017 International Research Institute of Stavanger, Norway Dec 6.
2018 International Symposium on Chemicals Risk Prediction and Management (ISCRPM) (Keynote). Dalian China April 25
2018 5th National Ecotoxicology Meeting of China (Keynote) Dalian, China April 26.
2018 South China Normal University Guangzhou, China April 30
2018 Guangzhou University Guangzhou China May 1
2018 Zhejiang University, Hangzhou, China May 2
2018 Shanxi University, Tiayuan, China May 3
2018 Society of Environmental Toxicology and Chemistry, Rome Italy May 14
2018 Association for the Sciences of Limnology and Oceanography, Victoria, Canada June 11
2018 Núcleo em Ecologia e Desenvolvimento Socioambiental de Macaé (NUPEM/UFRJ) Universidade Federal do Rio de Janeiro, Brazil June 19
2018 Department of Biology FURB - Universidade Regional de Blumenau, Brazil June 26
2018 Water Environment Research Foundation Compounds of Emerging Concern Research Needs: Where do we go from here? Lakewood, CO Sept 27.
2018 State Key Laboratory of Food Science and Technology, Jiangnan University Wuxi, China Oct 24
2018 Unidad de Química Sisal, UNAM. Yucatan, Mexico November 29
2019 National Water Research Institute, Fountain Valley California. Jan 11.
2019 Department of Biochemistry and Microbiology, University of Victoria, Canada March 15.
2019 Department of Chemistry, Bioscience and Environmental Engineering. University of Stavanger, Norway Mar 28.
2019 Department of Environmental Sciences, Zhejiang University, Hangzhou, China Apr 24.
2019 International Symposium on Chemical Risk Prediction and Management (Keynote). Guangzhou University Apr 26.
2019 6th National Ecotoxicology Meeting of China (Keynote) Guangzhou, China April 28.
2019 Núcleo em Ecologia e Desenvolvimento Socioambiental de Macaé (NUPEM/UFRJ) Universidade Federal do Rio de Janeiro, Brazil June 5.
2019 International Conference on Marine Pollution and Ecotoxicology. Plenary Speaker Hong Kong, June 11.
2019 11th International Symposium of Environmental Geochemistry. Keynote Speaker. Beijing University. Aug 9.
2019 School of Environmental Science and Technology, Dalian University of Technology Aug 11.
2019 School of Ocean and the Environment Dalian University of Technology, Panjin Campus. Aug 12.

2019 National Conference for Environmental Chemistry Tianjin, China Aug 16 and 17.
2019 National Geographic Educating the Educators Workshop, Qui Nonh, Vietnam Aug 19-20.
2019 National Aquaculture Research Institute, Nanning, China Aug 26.
2019 Institute of Hydrobiology, Chinese Academy of Science, Wuhan, Aug 30.
2019 International Symposium of Environmental Science and Technology, Hangzhou, China (Keynote and Plenary) Sept 26 and Sept 27.
2019 Department of Environmental Science and Engineering, Nankai University, Sept 28.

GRANTS

CURRENT SUPPORT

--Gulf of Mexico Research Initiative; Relationship of Effects of Cardiac Outcomes in fish for Validation of Ecological Risk (RECOVER) II. (University of Miami-PI) co-PI; 2018-2021. $6.0M/290,232

--California Department of Fish and Game; Impacts of climate change on pesticide bioavailability and sublethal effects on juvenile Chinook salmon in the Delta: Potential benefits of floodplain rearing PI 2018-2021. $963,408

--Metropolitan Water Districts of Southern California; Cost-share for CDFG grant. PI 2019-2021. $100,000

PAST SUPPORT

--Arkansas Science and Technology Authority: Basic Science "Metabolism of Off-Flavor Chemicals in Channel Catfish". PI 1992-1993 $36,780.

--USFDA "Efficacy of Copper Sulfate in Channel Catfish for the Treatment of Tetrahymena Infestations". PI 1993-1994 $33,250.

--Marine Biological Association of United Kingdom Scientific Fellowship "Role of Flavin-containing Monooxygenase in osmoregulation". PI 1993-1994 $3,000.

--UAMS Pilot Study Award "Use of Metallothionein as a Biomarker for Heavy Metal Contamination of Aquatic Ecosystems". PI 1993 $9,000.

--Arkansas Science and Technology Authority/Southern Farmer Services--Applied Science "Potential Feed Additives for Off-Flavor in Catfish". PI 1994-1996 $54,000.

--University of Mississippi Faculty Small Grant Award "Effect of Arsenic on Metallothionein Expression in Channel Catfish". PI 1995 $3,000.

--USFDA "Efficacy of Copper Sulfate in Channel Catfish for the Treatment of Ichthyopthirius Infestations". PI 1995-1996 $31,441.

--Southern Farmers Services, Inc. "Enhancing the Elimination of Off-Flavor from Channel Catfish: A Biochemical Approach". PI 1995-1997 $52,000.

--United States Environmental Protection Agency "Mississippi EPSCOR Program: Co-PI 1995-1997 $548,784.

--University of California at Davis Subcontract "Analysis of metallothionein and copper in rainbow trout". PI 1996-1997 $7,542.

--United States Department of Agriculture "Reduction of 2-Methylisoborneol uptake and induction of MIB metabolism and elimination in catfish". PI 1996-1999 $60,000.

--Marine Biological Association of United Kingdom Scientific Fellowship "Role of Flavin-containing Monooxygenase in Osmoregulation". PI 1997 $1,000.

--National Institutes of Health "Initiative for Minority Student Development" Co-PI 1997-1998 $467,704.

--Marine Biological Association of United Kingdom Scientific Fellowship "Role of Flavin-containing Monooxygenase in Osmoregulation". PI 1998 $1,000.

--Hudson River Foundation "Assessment of Environmental Estrogens in the Hudson River drainage system" PI 1998-1999 $78, 054.

--United States Geological Survey; Mississippi Water Resource Institute "Assessment of Environmental Estrogens in wastewater: Potential for developmental and Reproductive Toxicity in Fish" PI 1997-2000 $157,683.

--United States Department of Agriculture "Environmental Assessment for the Use of Copper in Fish Aquaculture" PI 1997-2001 $48,609.

--United States Department of Agriculture "Toxicological Evaluaton of a Cyanobacteria-Specific Biocide. Co-PI 2000-2001 $22,578.

--Louisiana Crayfish group "Fipronil Toxicity Testing the Crawfish (*Procambrius clarki*)"2000-2001 PI $46,922.

--United States Environmental Protection Agency "Effects of interacting stressors in agricultural ecosystems: mesocosm and field evaluation of multi-level indicators of wetland responses" Co-PI 1998-2001 $897,634

--United States Environmental Protection Agency "Mechanism of salinity induced toxicity of aldicarb in euryhaline fish" PI 1997-2001 $263,149.

--New York SEAGRANT "Estrogenicity of Municipal Sewage Treatment Plant Effluents: Vitellogenic and Estrogen Receptor Responses in Striped Bass" Co-PI 2000-2001 $239,151*

--University of California, Division of Agriculture and Natural Resources Hatch Funds "Relationships between salinity and pesticide accumulation in biota" 2001-2002 PI-$8,500.

--Southern California Coastal Water Research Project, "Threshold response of salmonid fish to dietary selenium for TMDL implementation" PI- 2001-2002. $17,370*

--University of California Institute for Mexico and the United States (UC-MEXUS) "Effects of contaminants present in the Colorado River Delta on nest success of yuma clapper rails (*Rallus longirostris yumanensis*) and burrowing owls (*Speotyto cunicularia*) Co-PI 2001-2002 $25,000.

--United States Civilian Research and Development Foundation "Research on the current status of Biodiversity and Water Quality in Dniester River, Moldova" Co-PI 2001-2002 $35,000.

--Coastal Marine Institute- Minerals Management Service "Use of Biological Endpoints in Flatfish to Establish Sediment Quality Criteria for Polyaromatic Hydrocarbon Residues and Assess Remediation Strategies" PI-2001-2003 $129,492.

--Hudson River Foundation. "Characterization of Estrogenic Effluent from Yonkers, NY: Determining the Composition and Potency of Estrogenic Chemicals."2002-2003 CoPI-$72,910.

--University of California Marine Council "Environmental Monitoring and Assessment of Environmental Estrogens in Marine Sediments of California" PI- 2002-2004 $443,379. (Co-PIs; David Sedlak, Ron Tjeerdema).

--University of California Water Resources Institute "Use of Bioassays to Assess the Water Qualtiy of Wastewater Treatment Plants for the Occurrence of Estrogens and Androgens. 2002-2004 $58,000

--San Francisco Estuarine Institute "Effects of nonylphenol on the estrogenic activity of selected aquatic pesticides"PI-2003-2005 $33,980.

--UC Mexus "Effects of contaminants on shellfish fisheries of Baja California Sur" Co-PI 2004-2005 $10,000.

--Water Environment Research Foundation "Use of Japanese Medaka as an On-Line Screening Platform for the Evaluation of Potable Water" PI-2003-2006 $309,868. (Co-PIs; David Hinton; Greg Woodside).

--Civilization Research Defense Fund (Department of Defense) "Accumulation and effects of Trace Elements on Fish Growth and Development" PI-2005-2007 $30,000.

--Southern California Coastal Research Project "Vitellogenin and Histopathology Endpoints in Hornyhead turbot from the Southern California Bight" PI-2007-2008 $72,000

--Orange County Sanitation District "Utilization of Sublethal Endpoints Across Biological Hierarchies to Evaluate Impacts of Wastewater on Fishery Health" PI-2005-2008 $150,000.

--USDA/NRI "Enantioselectivity of Current Chiral Insecticides in Soil and Sediment Environment" Co-PI 2005-2008 $405,000 (PI- Jay Gan).

--National Institutes of Health Superfund (University of Washington PI) Impact of hypersaline water on pesticide activation in Coho Salmon co-PI 2006-2009 $135,000.

--Southern California Coastal Research Project "Vitellogenin in Hornyhead turbot from the Southern California Bight" PI-2009 $8,400

--US Army Corp of Engineers "Do ordinance related compounds affect the endocrine system in reptiles?" PI- 2007-2009 $100,000.

--Calfed Bay Delta Program "Identifying the Causes of Feminization of Chinook Salmon in the Sacramento and San Joaquin River system: Co-PI- 2006-2010 $1,200.000 (PI-David Sedlak).

---California Department of Water Resources (Michael Anderson PI) Specialized environmental, biological, and technical support for activities related to development of Species Conservation Habitat (SCH) at the Salton Sea.; co-PI 2010-2011 $92,404.

--Bay Delta Science Program (University of California, Berkeley PI) Impact of urbanization on Chinook salmon, steelhead trout, and their prey: a case study of the American River. Co-PI 2011-2014 $55,000.

-- National Institutes of Environmental Health Science: Development of Stable Isotope Methods to Evaluate Bioavailability (Jay Gan PI) co-PI 2011-2014 $228,000

--Southern California Coastal Water Research Program, Evaluating Bioanalytical Methods. 2011-2014 $160,000.

---National Institutes of Environmental Health Science: Superfund Basic Research (University of Washington PI) Impact of hypersaline water on pesticide activation in Coho Salmon co-PI 2009-2015 $310,000.

---Riverside Department of Public Health. Residue Analysis of P-listed Pharmaceutical Containers for Warfarin and Nicotine. 2013-2014 $30,340

--Tobacco Related Disease Research Program : Assessing Toxicity of Tobacco Product Waste to Humans (San Diego State University PI) co-PI 2013-2017 $38,000.

--USGS Human and Ecological Health Impacts Associated with Water Reuse: Engineered Systems for Removing Priority Emerging Contaminants (University of South Carolina PI) co-PI 2015-2017 $83,333

--National Institutes of Environmental Health Science: Superfund Research Program- Exploring the Importance of Aging in Contaminant Bioavailability and Remediation (Jay Gan PI) co-PI 2014-2018 $868,669/$195,730

--Gulf of Mexico Research Initiative; Relationship of Effects of Cardiac Outcomes in fish for Validation of Ecological Risk (RECOVER) I. (University of Miami-PI) co-PI 2015-2018. $10.2M/834,754

PUBLICATIONS

1. D. Schlenk and W.H. Gerwick (1986) Dilophic acid, a diterpenoid from the tropical brown seaweed (*Dilophus guineensis*). Phytochemistry 26: 1081-1084.

2. D. Schlenk and D.R. Buhler (1988) Cytochrome P-450 and Phase II activities in the gumboot chiton, (*Cryptochiton stelleri*). Aquatic Toxicology 13:167-182.

3. D. Schlenk and D.R. Buhler (1989) Determination of multiple forms of cytochrome P 450 in microsomes from the digestive gland of (*Cryptochiton stelleri*). Biochemical and Biophysical Research Communications 163:476-480.

4. D. Schlenk and D.R. Buhler (1989) Xenobiotic biotransformation in the Pacific oyster (*Crassostrea gigas*). Comparative Biochemistry and Physiology 94C:469-475.

5. D. Schlenk and D.R. Buhler (1990) Flavin-containing monooxygenase activity in the gumbot chiton (*Cryptochiton stelleri*). Marine Biology 104:47-50.

6. D. Schlenk and D.R. Buhler (1990) The in vitro biotransformation of 2-aminofluorene in the western oyster (*Crassostrea gigas*). Xenobiotica 20:563-572.

7. D. Schlenk, P. Garcia and D.R. Livingstone (1991) Studies on myleoperoxidase activity in the common mussel (*Mytilus edulis*, L.). Comparative Biochemistry and Physiology 99C:63-68.

8. D. Schlenk and D.R. Buhler (1991) Flavin-containing monooxygenase activity in the rainbow trout (*Onchorynchus mykiss*). Aquatic Toxicology 20:13-24.

9. D. Schlenk and M. Brouwer (1991) Isolation of three copper metallothionein isoforms in the blue crab (*Callinectes sapidus*). Aquatic Toxicology 20:25-34.

10. D. Schlenk and D.R. Buhler (1991) Role of flavin-containing monooxygenase in the in vitro biotransformation of aldicarb in the rainbow trout (*Onchorynchus mykiss*). Xenobiotica 21:1583-1589.

11. D. Schlenk, D. Erickson, J.J. Lech and D.R. Buhler (1992) The in vivo disposition and biotransformation of aldicarb in rainbow trout (*Onchorynchus mykiss*). Fundamental and Applied Toxicology 18:131-136.

12. M. Brouwer, D. Schlenk, A. Ringwood, T. Hoexum-Brouwer (1992) Metal-specific induction of metallothionein isoforms in the blue crab (*Callinectes sapidus*) in response to single and mixed-metal exposure. Archives of Biochemistry and Biophysics 294:461-468.

13. D. Schlenk, A.R. Ringwood, T. Brouwer-Hoexum and M. Brouwer (1993) Crustaceans as models for metal metabolism: II. Induction and characterization of metallothionein isoforms from the blue crab (*Callinectes sapidus*). Marine Environmental Research 35:7-11.

14. D. Schlenk and D.R. Buhler (1993) Immunological characterization of flavin-containing monooxygenases in the liver of rainbow trout (*Oncorhynchus mykiss*): sexual- and- age-dependent differences, and the effect of trimethylamine on enzyme regulation. Biochimica Biophysica. Acta 1156:103-106.

15. D. Schlenk and M. Brouwer (1993) Induction of metallothionein mRNA in blue crabs treated with cadmium. Comparative Biochemistry and Physiology 104C:317-321.

16. D. Schlenk, M.J.J. Ronis, C.L. Miranda and D.R. Buhler (1993) Channel catfish liver monooxygenases: immunological characterization of constitutive cytochromes P450 and absence of active flavin-containing monooxygenases. Biochemical Pharmacology 45:217-221.

17. D. Schlenk (1993) A comparison of endogenous and exogenous substrates of the flavin-containing monooxygenases in aquatic organisms. Aquatic Toxicology 26:157-162.

18. D. Schlenk and C.T. Moore (1993) Distribution, uptake and elimination of the herbicide propanil in the channel catfish (*Ictalurus punctatus*). Xenobiotica 23:1017-1024.

19. D. Schlenk (1994) Effect of 2-Methylisoborneol on Cytochrome P450 expression in channel catfish (*Ictalurus punctatus*). Aquaculture 120:33-44.

20. U.A. Pillai, D. Schlenk, C. Frith, and P.W. Ferguson (1994) Effect of bleomycin-induced fibrosis on pulmonary metabolism of selected xenobiotics. Journal of the Louisiana State Medical Society 146:260-267.

21. D. Schlenk and C.T. Moore (1994) The effect of pH on the toxicity of copper sulfate to the ciliate protozoan (*Tetrahymena thermophila*). Bulletin of Environmental Contamination and Toxicoloy 53:800-804.

22. D. Schlenk, J. Bevers, A. Vertino, and C.E. Cerniglia (1994) Cytochrome P450-catalyzed S-oxidation of dibenzothiophene in the fungus (*Cunninghamella elegans*). Xenobiotia 24:1077-1083.

23. D. Schlenk and R.Li-Schlenk (1994) Characterization of liver flavin-containing monooxygenase of the smooth dogfish shark (*Squalus acanthus*) and partial purification of liver flavin-containing monooxygenase of the silky shark (*Carcharhinus falciformis*). Comparative Biochemistry and Physiology 109B:655-664.

24. D. Schlenk, M.J.J. Ronis, C. Miranda, and D. R. Buhler (1995) Effects of 2-methylisoborneol (MIB), and ethanol on the expression and activity of cytochrome P450s from the channel catfish (*Ictalurus punctatus*). Journal of Fish Biology 46:282-291.

25. L.D. Peters, D.R. Livingstone, S. Shehin, R.N. Hines, and D. Schlenk (1995) Characterization of hepatic flavin-containing monooxygenase from the turbot (*Scophthalmus maximus* L.). Xenobiotica 25:121-131.

26. Y.S. Zhang and D. Schlenk (1995) Induction and characterization of hepatic metallothionein expression from cadmium induced channel catfish (*Ictalurus punctatus*). Environmental Toxicology and Chemistry 14:1425-1432.

27. D. Schlenk, J. Nix and Y.S. Zhang (1995) Expression of hepatic metallothionein messenger RNA in feral and caged fish species correlates with residual mercury levels. Ecotoxicology and Environmental Safety. 31:282-286.

28. Rice, C.D. and D. Schlenk (1995) A comparision of immune function and P4501A activity following acute exposure to 3,3',4,4',5-pentachlorobiphenyl (PCB 126) in channel catfish (*Ictalurus punctatus*). Journal of Aquatic Animal Health. 7:195-204.

29. D. Schlenk (1995) Use of aquatic organisms as models to determine in the in vivo contribution of flavin-containing monooxygenases to xenobiotic biotransformation. Molecular Marine Biology and Biotechnology 4:323-330.

30. D. Schlenk, L. Peters, S. Shehin-Johnson, R.N. Hines, and D.R. Livingstone (1995) Differential expression and activity of flavin-containing monooxygenases in euryhaline and stenohaline flatfishes indicates potential osmoregulatory role. Comparative Biochemistry and Physiology 112C: 179-186.

31. E. Gallagher, P.L. Stapleton, D.H. Slone, D. Schlenk, and D.L. Eaton (1996) Channel catfish glutathione S-transferase isoenzyme activity toward *anti*-benzo[a]pyrene-*trans*-7,8-didhydrodiol-9,10-epoxide. Aquatic Toxicology 34:135-150.

32. D. Schlenk (1996) Role of biomarkers in ecological risk assessment. Human and Ecological Risk Assessment 2:251-256.

33. D. Schlenk, E.J. Perkins, W.G. Layher and Y.S. Zhang (1996) Correlating metrics of fish health with cellular indicators of stress in an Arkansas bayou. Marine Environmental Research 42:247-251.

34. D. Schlenk, L.D. Peters, and D. R. Livingstone (1996) Down regulation of piscine flavin-containing monooxygenase activity by decreased salinity in euryhaline flounder (*Platichthys flesus*). Marine Environmental Research 42:339-343.

35. D. Schlenk, E.J. Perkins, G. Hamilton, Y.S. Zhang, and W. Layher (1996) Correlation of hepatic biomarkers with whole animal and population/community metrics.Canadian Journal of Aquatic Sciences 53:2299-2309.

36. D. Schlenk, L.D. Peters, and D.R. Livingstone (1996) Correlation of salinity with flavin-containing monooxygenase activity but not cytochrome P450 activity in the euryhaline fish (*Platichthys flesus*). Biochemical Pharmacology 52:815-818.

37. E.J. Perkins, B. Griffin, K.M. Chan, and D. Schlenk (1997) Sexual differences in mortality and sublethal stress in channel catfish following a 10 week exposure to copper sulfate. Aquatic Toxicology 37:327-339.

38. D. Schlenk, M. Chelius, S. Khan, and K.M. Chan (1997) Characterization of hepatic metallothionein expression in channel catfish (*Ictalurus punctatus*) by reverse transcriptase polymerase chain reaction. Biomarker 2:161-167.

39. B.R. Griffin, M.S. Hobbs, J.L. Gollon, D. Schlenk, F.F. Kadlubar, and C.D. Brand (1997) Effect of waterborne copper sulfate exposure on copper content of liver and axial muscle of channel catfish. Journal of Aquatic Animal Health 9:140-147.

40. E.J. Perkins and D. Schlenk (1997) Comparisons of uptake and depuration of 2-methylisoborneol in male, female, juvenile and 3MC-induced channel catfish. Journal of the World Aquaculture Society 28:158-164.

41. D. Schlenk, D. Stresser, A. Nimrod, L. Arcand and W.H. Benson (1997) Influence of B-naphthoflavone and methoxychlor pretreatment on the biotransformation and estrogenic activity of methoxychlor in channel catfish (*Ictalurus punctatus*). Toxicology and Applied Pharmacology 145:349-356.

42. D. Schlenk, R. Pittman, L.A. Wolford, J. Steevens, and K.M. Chan (1997) Effects of arsenate, aresenite, and the herbicide, monosodium methyl arsenate on hepatic metallothionein and lipid peroxidation in channel catfish. Comparative Biochemistry and Physiology 118C:177-183.

43. D. Schlenk, A. Elalfy and D.R. Buhler (1997) Down regulation of hepatic flavin-containing monooxygenase activity by 17B-estradiol in rainbow trout (*Oncorhynchus mykiss*). Comparative Biochemistry and Physiology 118C: 199-202.

44. D. Schlenk (1998) Invited review: Occurrence of flavin-containing monooxygenases in non-mammalian eukaryotic organisms. Comparative Biochemistry and Physiology 121C: 185-195.

45. D. Schlenk and C.D. Rice (1998) Effect of zinc and cadmium treatment on hydrogen peroxide-induced mortality and expression of cellular glutathione and metallothionein in a teleost hepatoma cell line. Aquatic Toxicology 43:121-129.

46. D. Schlenk and A. El-Afy (1998) Expression of branchial flavin-containing monooxygenase is directly correlated with salinity-induced aldicarb toxicity in the euryhaline fish (*Oryzias latipes*). Marine Environmental Research 46:103-106.

47. D. Schlenk, D. M. Stresser, J. Rimoldi, L. Arcand, J. McCants, A.C. Nimrod, and W.H. Benson (1998) Biotransformation and estrogenic activity of methoxychlor and its metabolites in channel catfish (*Ictalurus punctatus*) Marine Environmental Research 46:159-162

48. C. D. Rice, D. Schlenk, J. Ainsworth, and A. Goksoyr (1998) Cross-reactivity of monoclonal antibodies against peptide 277-294 of rainbow trout CYP1A1 with hepatic CYP1A among fish. Marine Environmental Research 46:87-91.

49. A. El-Alfy and D. Schlenk (1998) Potential mechanisms of the enhancement of aldicarb toxicity to Japanese medaka (Oryzias latipes), at high salinity. Toxicology and Applied Pharmacology 152:175-183.

50. D. Schlenk, J.L. Gollon, B.R. Griffin (1998) Efficacy of copper sulfate for the treatment of ichthyophthiriosis in channel catfish. Journal of Aquatic Animal Health 10:390-396.

51. D. Schlenk, K.B. Davis and B. Griffin (1999) Relationship between expression of metallothionein and sublethal stress in channel catfish following exposure to copper sulfate.Aquaculture 177:367-379.

52. E. J. Perkins and D. Schlenk (1998) Immunochemical charaterization of hepatic cytochrome P450 isozymes in the channel catfish: assessment of sexual, developmental, and treatment-related effects. Comparative Biochemistry and Physiology 121C: 305-310.

53. E. J. Perkins, A. El-Alfy and D. Schlenk (1999) In vitro sulfoxidation of aldicarb by hepatic microsomes of channel catfish *Ictalurus punctatus*. Toxicological Sciences 48:67-73.

54. G.M. Dethloff, D. Schlenk, S.Khan and H. C.Bailey (1999)The effects of sublethal copper toxicity on rainbow trout (*Oncorhynchus mykiss*) in soft water. I. Blood and biochemical parameters. Archives of Environmental Contamination and Toxicology 36:415-423.

55. G.M. Dethloff, D. Schlenk, J.T. Hamm, and H.C. Bailey (1999) The effects of copper and copper/zinc mixtures on physiological parameters of rainbow trout (*Oncorhynchus mykiss*). Ecotoxicology and Environmental Safety 42: 253-264 .

56. J.A. Steevens, M. Slattery, D. Schlenk, A. Aryl, and W.H. Benson (1999) Effects of ultraviolet light and polyaromatic hydrocarbon exposure on sea urchin development and bacterial bioluminescence. Marine Environmental Research 48: 1-19.

57. D. Schlenk, E.J. Perkins, W.B. Hawkins (1999) Effect of ethanol, clofibric acid and temperature on the uptake and elimination of 2-methylisoborneol in channel catfish (*Ictalurus punctatus*). Fish Physiology and Biochemistry 21:173-178.

58. D.Schlenk (1999) Necessity of defining biomarkers for use in ecological risk assessments. Marine Pollution Bulletin 39:48-53.

59. B.R. Griffin, K.B. Davis, D. Schlenk (1999) Effect of simulated copper sulfate therapy on stress indicators in channel catfish. Journal of Aquatic Animal Health 11:231-236.

60. E J Perkins and D.Schlenk (2000) In vivo metabolism, acetylcholinesterase inhibition, and toxicokinetics of aldicarb in channel catfish (*Ictalurus punctatus*). Toxicological Sciences 53:308-315.

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62. S. Thompson, F. Tilton, D. Schlenk, and W.H. Benson. (2000) Comparative vitellogenic response in three teleost species: Extrapolation to in situ field studies. Marine Environmental Research 50: 185-189.

63. E. Perkins, B.C. DeBusk and D.Schlenk (2000) Isolation and characterization of a novel cytochrome P450 (CYP2 family) isoform from channel catfish. Fish Physiology and Biochemistry 22:199-206.

64. D.Schlenk, W.C. Colley, A. El-Alfy, and R. Kirby (2000) Effects of the Oxidant, Potassium Permanganate, on the Expression of Gill MT mRNA and its Relationship to Sub-lethal Whole Animal Endpoints in Channel Catfish. Toxicological Sciences 54:177-182.

65. D. L. Straus, D. Schlenk, and J. E. Chambers (2000) Hepatic microsomal desulfuration and dearylation of chlorpyrifos and parathion in fingerling channel catfish: lack of effect from aroclor 1254 Aquatic Toxicology 50:141-149.

66. B.C. Debusk, S. Kumir J. Rimoldi and D.Schlenk (2000) Phase I and II enzyme and activity levels in the gumboot chiton *Cryptochiton stelleri* following exposure to a dietary bromo-phenol, lanosol. Comparative Biochemistry and Physiology 127C:133-142.

67. D. Schlenk, E.J. Perkins, and B.C. DeBusk (2000) 2-Methylisoborneol disposition in three strains of catfish: absence of biotransformation. Fish Physiology and Biochemistry23:225-232.

68. D.B. Huggett, I.A. Khan, J.C. Allgood, D.S.Block, D. Schlenk. (2001) Organochlorine Pesticides and Metals in Select Botanical Dietary Supplements. Bulletin of Environmental Contamination and Toxicology. 66:150-155

69. A. Elalfy, S. Grisle, and D. Schlenk (2001) Characterization of Salinity-enhanced toxicity of aldicarb to Japanese medaka: sexual and developmental differences. Environmental Toxicology and Chemistry 20:2093-2098.

70. D.B.Huggett, D.Schlenk, and B.R. Griffin (2001) Bioavailability of Copper in a Oxic Stream Sediment Receiving Aquaculture Effluent. Chemosphere 44:361-367.

71. B. Larsen and D. Schlenk (2001) Effect of Salinity on Flavin-Containing Monooxygenase expression and activity in Rainbow Trout (Oncorhynchus mykiss). Journal of Comparative Physiology B 171: 421-429.

72. F. Tilton, W. H. Benson, and D. Schlenk (2001),Elevation of serum 17-β-estradiol in channel catfish following injection of 17-β-estradiol, ethynyl estradiol, estrone, estriol and estradiol-17-β-glucuronide. Environmental Toxicology and Pharmacology 9:169-172.

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